The SCIENTIFIC MONTHLY

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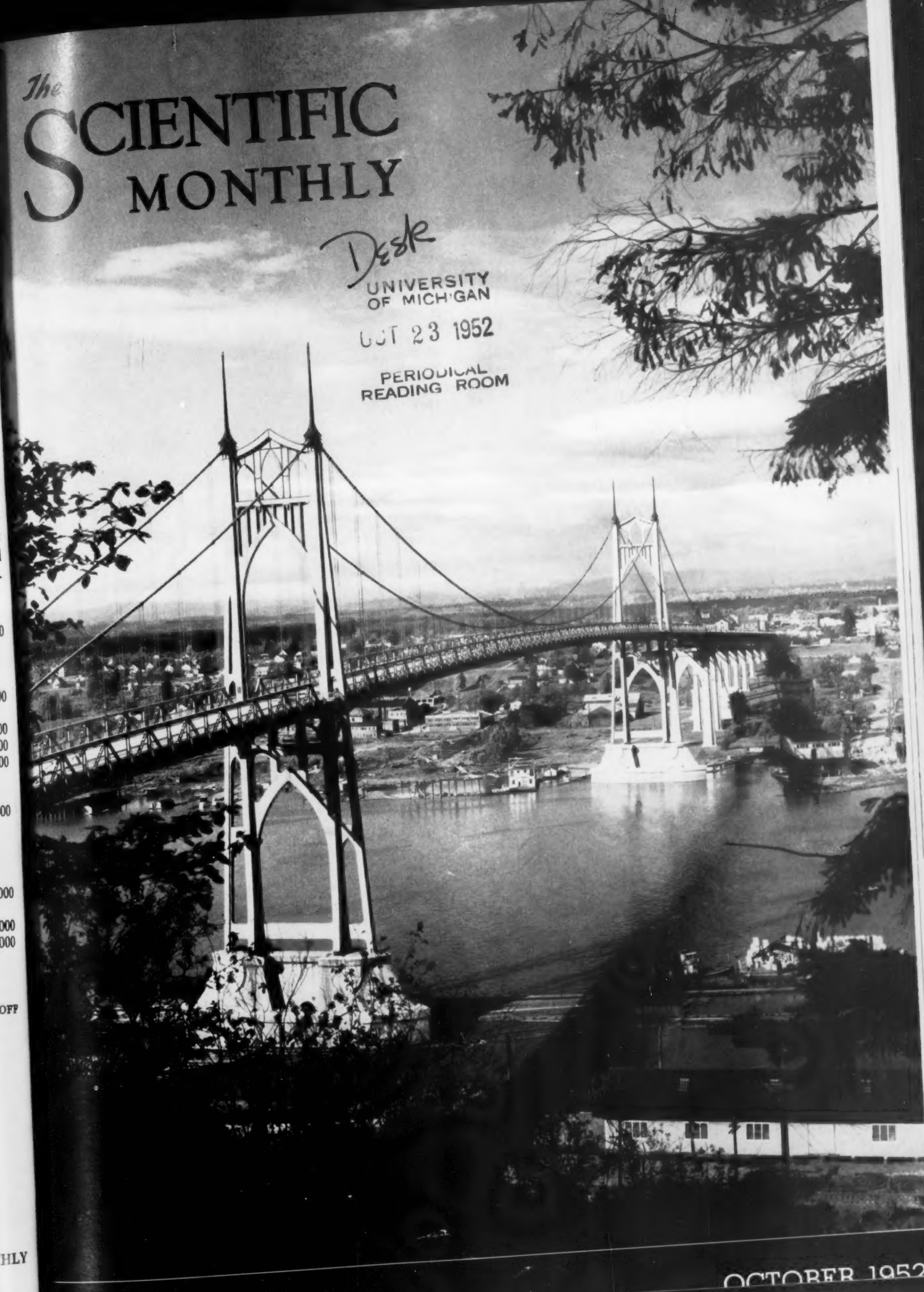

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Contents

Annual Meeting, AAAS, St. Louis, Missouri, December 26–31, 1952

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Science and Technology

(From the Month's News Releases)

Manipulator

To prevent the loss or deformation of the tiny, 200-mesh stainless steel specimen screens used in electron microscope work, Emanuel Kafig, a Navy civilian employee, has designed and constructed a magnetic manipulator about the shape and size of a fountain pen. The instrument can be made in various sizes at relatively small cost, and might also prove useful in commercial operations where small metal parts are used in manufacturing or fabricating.

Cement It

An all-purpose liquid cement will seal and bond permanently any kind of surface to any other kind, and stop all leaks instantly. For example, according to the manufacturer, it will stop leaks in auto gas tanks without removal of gas. The liquid is unaffected by water, alcohol, naphtha, oil, or gas, but may be removed with acetone if necessary.

Another fast-setting liquid has an initial setting time of 30 seconds when mixed with plain Portland cement and has been developed for extreme pressure leaks.

Self-contained Illumination

An electrically lighted magnifier comes equipped with either a battery-powered handle or a handle that may be connected with a 110-volt power source. A non-illuminating handle and a metal tripod are supplied as accessories without extra cost. The lens system magnifies five times, has a wide, flat field, and practically no spherical and chromatic aberration and distortion.

Magnetic Floor Sweeper

A high-powered Alnico V magnetic tube mounted between two neoprene wheels, and operated like a carpet sweeper, instantly picks up tacks, nails, nuts, screws, or any other piece of ferrous metal. It is inexpensive, and makes it simple to keep factory floors, dock areas, parking lots, beauty shops, and fitting room floors cleared of metal scraps.

Repellent

A liquid that may be used to keep dogs, cats, and rabbits away from evergreens, lawns, and gardens is nontoxic, nonodorous, and will not wash off. It is also obtainable as a powder for use on chairs and rugs.

New Journals Announced

The Annals of American Research, by the Public Affairs Press, 2153 Florida Ave., Washington 8, D. C. . . . *Applied Microbiology,* to begin publication in January 1953, under the auspices of the Society of American Bacteriologists. Bimonthly at $7.50 per year from Williams & Wilkins Company, Baltimore, Md. . . . *D. D. S.,* a digest of dental science, scheduled for October publication. Lester R. Cahn, Editor-in-Chief, 888 Park Ave., New York 21. Monthly, $5.00; foreign $6.00. . . . *Laboratory Investigation,* a journal of technical methods and pathology, sponsored by the International Association of Medical Museums. Successor to *Bulletin of the International Association of Medical Museums.* Editor, Thomas D. Kinney, Cleveland City Hospital, 3396 Scranton Rd., Cleveland 9, Ohio. Quarterly at $8.00 from Paul B. Hoeber, Inc., 49 E. 33rd St., New York 16. . . . *The Personnel and Guidance Journal,* successor to *Occupations.* Official journal of the new American Personnel and Guidance Association. Will appear in October under the editorship of William D. Wilkins. $6.00 per year with membership in one of the APGA divisions.

Dog of the Year

Jumbo, a female black-and-brown police-type dog, was chosen as the medical research dog of the year for National Dog Week in September. In a perfusion experiment at the Surgical Research Laboratories, State University Medical Center, Brooklyn, Jumbo was connected to a heart-lung machine by cannulas; then her blood was completely circuited so that none flowed through the heart or lungs. Selected from among candidates all over the country, Jumbo was presented with a silver inscribed collar by the National Society for Medical Research as having made the most important contribution to medical research and to mankind during 1952.

Air Conditioning in Miniature

A desiccating device, designed to eliminate fogging, freezing, and dirt infiltration of aircraft gunsights, is being developed for industrial applications. Its automatic reactivating cycle that depends on altitude changes will be altered so that the instrument may be used for adding machines, time clocks, and other equipment located in tropical climates; for instrument storage cabinets, small electromechanical systems, and food cabinets on marine craft; and for storage cabinets for use in medicine, chemistry, electronics, and other fields. The present model weighs 13 ounces and will condition the air in any airborne instrument containing up to one cubic foot volume.

News of the Atomic Age

The first gamma ray generator of its kind, designed to give complete uniform total body irradiation of target materials, has been designed and built by scientists of the Naval Medical Research Institute, Bethesda, Md. Source of the gamma rays will be Co^{60} in 100

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3-inch capsules containing about 200 g each. The generator is shaped somewhat like a large bottle and is composed of 60 individual $1\frac{1}{2}$-inch aluminum alloy pneumatic tubes into which the capsules are loaded by remote control from $3\frac{1}{4}$-ton shipping container, to which the designers refer as "The Monster." In especially constructed shielding a T-shaped barrier divides the building into two exposure rooms and a control room. Before the radiocobalt can be transferred from one room to the other, a warning bell sounds, giving an investigator ample time to use the safety switch that prevents operation of the generator mechanism.

The first atomic energy reactor in California has been demonstrated by North American Aviation at its Downey plant. Under a contract with the Atomic Energy Commission, a water boiler neutron reactor of very low power was built as part of a facility for making reactor physics measurements to enlarge the essential information upon which reactor development is based. Although this type of reactor is completely controllable by mechanical means, it is unique in that if the controls fail, the heat produced by fission would raise the temperature of the water solution sufficiently to stop power production. At that point emergency control rods could be employed to restore the reactor to a neutral condition.

A new "personal" dosimeter is a small, easy-to-use, low-cost instrument for the estimation of gamma radiation, suitable for use by civilians. It is 2 inches long, weighs only an ounce, and contains a chemical solution that changes color when exposed to gamma rays. The degree of exposure may be determined by matching the color of the liquid against a color chart printed on the outside.

An efficient boron trifluoride neutron counter utilizes a guard-ring type of construction and is available in pressures of 150 and 12 cm Hg, in three standard sizes: $1'' \times 6''$, $1'' \times 12''$, and $1'' \times 20''$ active lengths. Of aluminum construction, the whole counter is helium leak-tested before filling.

Film Conversion

A system for converting silent films into sound motion pictures permits the magnetic recording and playback of sound directly on standard silent film, perforated along both edges. Processes previously used cost about $12\frac{1}{2}$¢ per foot to convert to sound. Standard silent films can now be converted for only $3\frac{1}{2}$¢ per film foot.

This huge aerial, 700 feet long, and capable of receiving radio waves from individual parts on the sun's surface, was developed by W. N. Christiansen, CSIRO research officer shown standing by one of the 32 receivers. Largest aerial of its type in the world, it is located at Pott's Hill, near Bankstown, a suburb of Sydney, Australia.

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How Bridges Have Increased Man's Mobility*

D. B. STEINMAN

D. B. Steinman, the internationally famous bridge engineer, received his Ph.D. at Columbia University. He was professor of civil engineering at the University of Idaho (1910–14), was special assistant to Gustav Lindenthal on the design and construction of the Hell Gate Arch and other bridges (1914–17), and then was professor in charge of civil and mechanical engineering at the City College, New York. Since 1920 he has been in private practice and has served as designing or consulting engineer in the construction of bridges on five continents. Six of his bridges have been honored in the annual Artistic Bridge Awards. He has twice received the Norman Medal, the highest award of the American Society of Civil Engineers, in addition to two other awards of the society. In 1952 he was presented with the highest award of the National Society of Professional Engineers for his outstanding professional contributions and achievements.

THE past century has seen the transformation of America from a young pioneer settlement into a great and flourishing nation, taking its place in the leadership of the world. From forest and wilderness, mountain and desert, America has been metamorphosed into a rich and dynamic land, first expanded and tied together by isolated wagon roads, canals, and railroads, and now crisscrossed with magnificent systems of paved highways, boulevards, scenic parkways, thruways, and superhighways. From a nation dependent on pack horse, oxcart and prairie schooner, America has become a nation on wheels.

In this shrinking of distances and speeding of travel, bridges have played an indispensable role. The nation has become more closely knit together. Remoteness and isolation have been replaced by unity and mobility.

As late as 1923, speaking at a New York meeting of the American Society of Civil Engineers, I advocated that our large municipal bridges of the future be planned for motor vehicle traffic and that our rapid transit tracks be kept underground in subways and tunnels. A prominent older member dissented; he said it did not seem fair for the city to build bridges for the pleasure of the privileged few who happened to be wealthy enough to own automobiles. Today, less than thirty years later, the picture is transformed. We now have 50 million motor vehicles rolling over our paved roads, parkways, bridges, and express highways. The luxuries of yesterday have become the necessities of today. In America, almost every family nowadays demands, and somehow secures, at least one auto-

* Based on an address presented at the Centennial of Engineering in Chicago, September 1952.

Roebling's Niagara Falls railroad suspension bridge was built of wire and wood. After 42 years of service it was replaced in 1897.

mobile, and such recent luxuries as telephones, electrical appliances, radios, and television sets are now taken for granted in practically every home.

How has this transformation been accomplished? America and its greatness have been built by the courage of the pioneer, the spirit of individual and concerted enterprise, and the grit and resourcefulness of the engineer. We hear much of the "Four Freedoms," but we are in danger of losing sight of the basic freedoms on which this nation was founded and on which it achieved its greatness. These are: Freedom of Vision, Freedom of Enterprise, Freedom of Incentive, and Freedom of Achievement.

These four freedoms spell America. They also explain much of the success we have had in developing a transportation system that involved the building of many of the world's greatest bridges.

The early settlers were limited in mobility to footpath, pack trail, and local wagon road. And then, in succession, came the building of canals, railroads, and modern highways. Each of these in turn required bridges, and each depended upon the bridge builder's art for feasibility and realization. The American spirit—at once daring and practical—is peculiarly adapted to excel in such a development.

During the nineteenth century, the principal demand for bridge construction in the United States was in the building and development of the railroads. At the turn of the century, many of the railroad bridges were being replaced or reconstructed to provide increased strength and clearance for the rapidly increasing size, weight, and clearance of trains and locomotives. Even thereafter, railroad extension involved the building of such monumental spans as the Hell Gate Arch and the Sciotoville continuous bridge.

Since about 1920, however, there has been no further extension of the rail systems, and the economic plight of the railroads has limited the improvement of existing construction. Instead, the phenomenal increase in highway traffic has created a new phase of bridge construction in which there are both the economic justification for bridges of unprecedented dimensions over crossings that previously had to be left unspanned and the need for myriads of smaller bridges and grade separation layouts.

There are more than 90,000 steel bridges on 240,000 miles of railroad in the United States, and the aggregate length of these is more than 1500 miles. But the number of highway bridges, both steel and concrete, in the United States probably exceeds 250,000 on the 3,000,000 miles of roads and highways. The aggregate investment in these highway bridges amounts to over $3,000,000,000.

Cities located at junctions of rivers are particularly dependent upon bridges for their development, and thereafter for the mobility of their population. The city of Pittsburgh has sixteen highway bridges and seven railroad bridges spanning the Allegheny and Monongahela rivers. In New York

The Kill van Kull arch at Bayonne, N. J., built by the Port of New York Authority in 1931, is the world's longest arch span.

City, in a single day, more than 750,000 automobiles and trucks cross the highway bridges entering Manhattan—450,000 on twelve free bridges (including 90,000 on the Queensboro Bridge and 80,000 on the Manhattan Bridge), and 300,000 on three toll bridges (George Washington, Triborough, and Henry Hudson)—besides more than 700,000 passengers daily on rapid transit trains and electric trolley cars.

Individual bridges have proved of tremendous importance as the key factors in the development of cities, regions, and the nation as a whole. The Eads Bridge over the Mississippi River at St. Louis, completed in 1874, was the essential link in the development of the transcontinental railroad system, and its significance in "the winning of the West" has been well recognized. At the same time, the Eads Bridge was of prime importance to St. Louis, establishing it as a focal railroad crossing and as one of the most important cities on the Mississippi. The influence of the construction of a bridge on the transportation pattern of a region or of the nation, affecting its population, industry, and commerce, has been repeated many times over the whole length and breadth of the land.

Probably no bridge has had more influence on the growth of a city than the Brooklyn Bridge, completed in 1883. The population of Brooklyn was soon doubled, and the erstwhile village became a thriving city and an integral part of the newly formed city of greater New York. The three additional East River bridges, which had to be built in quick succession, completed the transformation of Brooklyn into the largest borough of the enlarged metropolis and the creation of the great new borough of Queens.

The seven longest spans in the world are in the United States: Golden Gate, 4200 feet; George Washington, 3500 feet; Tacoma Narrows, 2800 feet; Transbay, 2310 feet; Bronx-Whitestone, 2300 feet; Delaware Memorial at Wilmington, 2150 feet; Detroit-Ambassador Bridge, 1850 feet. All these are of the suspension type and all are highway toll bridges.

The largest bridge project in the world consummated to date is the Transbay Bridge between San Francisco and Oakland, completed in 1936 at a cost of over $77,000,000. Its total length of eight miles includes two joined suspension bridges of 2310 feet main span each, a cantilever bridge of 1400 feet main span, and other connecting spans. A record foundation depth of 240 feet was reached for one of the piers.

The world's longest span is the Golden Gate Bridge, also at San Francisco, completed in 1937 at a cost of $35,000,000. The main span, 220 feet above the water, is 4200 feet between towers 746 feet high. The two main cables are 36½ inches in diameter, the largest constructed to date.

The George Washington Bridge, over the Hudson River at New York, with a main span of 3500 feet, was opened in 1931 at an initial cost of $60,000,000. It has four main cables, each 36 inches in diameter. The present deck carries eight lanes of highway traffic, and provision has been made for the addition of a lower deck.

With wider and more numerous crossings required, the bridge builders of the U. S. and Canada have achieved and retained world leadership in almost every modern type of bridge, including not only the unrivaled suspension bridges, but also the world's longest spans in cantilevers, steel arches, continuous trusses, simple trusses, timber spans,

Charter Oak Bridge over the Connecticut River at Hartford is of the continuous girder type. Designed by Robinson & Steinman, it received the 1942 Artistic Bridge Award.

swing spans, vertical lift spans, bascule spans, and transporter bridges. American engineers have also pioneered in inventing or developing new types, including movable bridges, rigid frames, the Wichert truss, and prestressed concrete bridges. About the only types in which European engineers have established new records are concrete arches, prestressed concrete spans, and steel girder spans; the differences of emphasis and development are explained by differences in tradition (the masonry arch), differences in economics (scarcity of steel), and differences in design preferences and fabrication customs.

For spans of unusual magnitude and cost, and also for interstate and international crossings, toll bridges have come to be the solution to the financing problem. Up to 1929, most of the toll spans were under private ownership, but the more recent toll bridges in the United States have all been built by public commissions or "bridge authorities."

Toll bridges are financed, as a rule, by issuing revenue bonds secured only by prospective earnings, so that the user pays for them until they become free, instead of the cost being added to the general tax burden. The motoring public has thus secured the benefit of many needed bridge crossings where such facilities would otherwise have remained unattainable. There are now more than 165 toll bridges in the United States, representing a total investment of over $500,000,000. Only about 80, with an investment of about $100,000,000, are privately owned, and this number is rapidly dwindling.

Bridges are an index of civilization. With the expanding needs of intercommunication and travel and with the advances in technical science and construction skill, the progress of bridge building has been marked by a rapidly accelerating tempo. The past century has encompassed more advances in the science and art than all the preceding centuries, and the past generation has again more than doubled that record in the attainment of greater and still bolder spans.

In recent years, new frontiers of unprecedented span lengths have been opened. The world's record span length for suspension bridges has been more than doubled, from 1750 feet in the Phila-

Another Steinman-designed bridge is the three-level bridge crossing for the Route 4 Parkway over the New Jersey Turnpike, which was constructed after the bridge was built.

delphia-Camden Bridge in 1926 and 1850 feet in the Detroit-Ambassador Bridge in 1929, to startling new records of 3500 feet in the George Washington Bridge in 1931 and 4200 feet in the Golden Gate Bridge in 1937. The world's record for steel arches was increased from 977½ feet in the Hell Gate Arch Bridge in 1917 to 1650 feet in the Sydney Harbor Bridge in Australia in 1932, and 1652 feet in the Bayonne Bridge over Kill van Kull in 1931. The world's record span length for concrete arches was increased from 450 feet at Annecy, France, in 1938 to 866 feet at Sando, Sweden, in 1943.

Never before in the history of bridge engineering have such amazing strides been recorded. Length of span is one of the measures by which bridges are judged, since it provides a convenient over-all index of related advances in the art, including improvements in design, theory, economics, new materials, new bridge types, and methods of erection. A generation ago, the cantilever type was dominant. The famous Quebec Bridge, completed in 1917 after two historic erection catastrophes, held the world's record span length of 1800 feet. Since then, however, with improvements in suspension bridge construction, the cantilever bridge has dropped out of the race and has yielded its supremacy to the suspension type. The world's seven longest spans are suspension bridges.

Bridges of still greater span length and magnitude are already in the planning stage. I have in fact designed bridges for proposed locations over the Narrows at New York and over the Strait of Messina in Italy with spans of 4620 and 5000 feet, respectively. A generation ago, the feasibility of a span of 3000 feet was seriously questioned. Now we can state with confidence that suspension bridge spans up to 10,000 feet are not only practicable, but may be expected.

This is true despite the startling destruction in 1940 of the 2800-foot span Tacoma Narrows Bridge by catastrophic amplification of aerodynamic oscillations. Similar failures with smaller spans had occurred a century earlier and had remained a mystery; but now better tools of research and analysis were available for mastery of the problem. By combining three previously unrelated sciences—the deflection theory of suspension bridges, the mathematical theory of vibration analysis, and the science of aerodynamics—a new science of suspension bridge aerodynamics has been developed, permitting predictive control, solution, and cure of the problem. Solutions in two directions have been made available, one by scientific methods of increasing the stiffness of the structure to resist the action, and the other by scientific design of aerodynamically stable sections, thereby eliminating the cause of the action. Assured safety of future suspension bridges has thus been achieved, without sacrificing economy and graceful design.

As the result of progress in the science and art of foundation design and construction, new records have been achieved in the magnitude and depth of bridge foundations sunk under the most difficult conditions. For the Huey P. Long Bridge over the Mississippi River at New Orleans, completed in 1935, a record 170-foot foundation depth was reached, using the artificial sand island method. For the Transbay Bridge between San Francisco and Oakland, a new foundation method was devised, using dome-capped caissons to regulate the sinking by controlling the release of air pressure. The piers were thus carried down to rock 240 feet below the water surface—the greatest foundation depth thus far attained.

Thus, the bridge engineer, in addition to his knowledge of superstructure design, must be an expert on geology, hydraulics, methods of subsurface exploration, foundation design, and foundation construction.

Development of longer-span bridges has created an impelling need for improved bridge materials. This has taken two directions: one the development of higher strength steels, and the other the development of lighter weight metals for structural use. The economy of utilizing stronger or lighter metal obviously increases with the span length.

The high-strength materials that have thus far been successfully used in bridge construction have included alloy steels (such as silicon steel, nickel steel, manganese steel, and chrome-nickel steel), heat-treated carbon steel, and cold-drawn high-carbon bridge wire. Materials with three or four times the safe working strength of ordinary steel have been developed.

The principal lightweight material has been structural aluminum. Since 1932 aluminum has been used in the construction of several notable bridges in the United States, England, and Canada, as well as in military bridges and pontons. New possibilities have thus been opened for the future attainment of longer spans.

During the past twenty-five years, attention has also been concentrated on the attainment of beauty in bridges. Annual Artistic Bridge Awards, inaugurated in the United States in 1928, have called attention to the importance of making bridges beautiful. New artistic goals have been achieved through beauty and harmony of composition,

Perspective drawing of Brooklyn Bridge made from John Roebling's plans before the bridge was built.

through beauty of line, form, and proportion, through color and illumination.

To build their famous aqueducts, the ancient Romans used thousands of tons of masonry in massive piers and arches to carry a small conduit for water supply. Today, graceful, airy spans carry thousands of tons of useful load—seemingly by magic. Ponderous proportions are no longer the visual expression of power. People must live with the structures we build. Our work becomes a part of the landscape, to mar or to grace. If we are to be true to our trust, each structure we raise and each span we build must uplift and inspire. The rainbow spans of tomorrow will have simplicity of form, beauty of line, grace of proportion, harmony of color, and radiant illumination.

I think that no one, unless he be completely without feeling, can remain unmoved at the sight of a beautiful bridge. In span after span, bridge designers have demonstrated that beauty can be secured without sacrificing utility or economy. They are directing their efforts toward producing the most beautiful designs in the structural material itself, whether steel or concrete, by developing forms that express the spirit of the material—its strength, its power, and its grace.

The two bridge types that most naturally yield beauty of form, line, and proportion are the arch and the suspension bridge. The arch contributes something dynamic—a feeling of a powerful thrust created in the span and carried down the curving arc to be resisted at the abutments. To attain the most creative and inspiring beauty of composition in steel bridge design, the suspension type is ideal. The graceful curve of the cables is the most natural and therefore the most attractive of all bridge outlines, and the vertical hangers, like the strings of a harp, are the most harmonious and satisfying form of filling members. The dominant pylons divide the crossing into three spans of artistic proportions. Between the pierced towers the arching roadway slowly inclines upward to meet the swift downward sweep of the cables. The ensemble is a natural composition of power and symmetry.

The bridge designer of this era must be both engineer and artist. To a thorough understanding of structural design and function he must add a strong feeling, both innate and trained, for beauty of form, line, and proportion. Architects, before they can help the engineer, must learn to understand and appreciate this new material—steel—and not regard it merely as a skeleton to be concealed or clothed in some foreign raiment.

In addition to artistic form and line, the graceful, arching spans of tomorrow, like their prototype, the rainbow, will have brightness and warmth of color to satisfy a color-minded people. Instead of a black or gray intrusion or disfiguration, the bridge

of tomorrow will be a thrilling part of the landscape. Illumination is a comparatively new but vigorous contribution to the aesthetic aspect of bridges. "Painting with light" will be an integral part of their design. With phosphorescent color and fluorescent radiance, unforgettable luminous effects will be produced. By night the rainbow span will be a radiantly glowing arc.

A bridge is the embodiment of the combined effort of human heads and hearts and hands. It is an expression of man's creative urge and of his conquest of the forces of nature. When viewed in the glow of sunset or the enchantment of moonlight, it is, indeed, "a poem stretched across a river."

In all this amazing evolution of spans from primitive to modern, from simple to complex, from small to gigantic, from commonplace to inspiring, there has been a unifying spirit dominating bridge builders from generation to generation. It has been a spirit of vision, of invention, of courage, of sacrifice, and of consecration. From the Brothers of the Bridge in the Middle Ages to the bridge builders of today, those who conceived and created spans for the race of man have done so in a spirit of dedication. They were building, not monuments for themselves, but enduring instruments of service for their fellow-men. They blazed the trails, cleared away obstacles, broke down barriers, and spanned the rivers and chasms that halted the progress of humanity. They did this, not alone for their own generation, but for the generations of men to come.

In our review of the epic of bridge building through the centuries, one impression is dominant.

Brooklyn Bridge at night. This most famous of all bridges was designed by John A. Roebling (1867–69), built by his son, Washington A. Roebling (1869–83), and reconstructed by D. B. Steinman (1950–53).

Proposed Messina Strait Bridge designed by D. B. Steinman would be the world's longest span (main span, 5000 feet). It would carry railroad and highway traffic and has been designed to resist hurricanes and earthquakes. Foundations of the main piers would be in 400 feet of water.

In every great bridge project there must be, first, the vision and then the compelling endeavor to bring that vision to reality. Through the ages, the spirit of the bridge builder has been: "From dream to deed—from vision to accomplishment." That has been the spirit of the engineering profession, and it has likewise been the spirit of America.

The bridge builders who preceded us dreamed their dreams and wrought their dreams, giving health, strength, and even life itself as the price of achievement. This generation is profiting by the work of the pioneers and is tackling even greater tasks. Whatever we may accomplish will in turn be eclipsed by those who follow us. In our large cities and over our mighty rivers we see great bridges, beautiful bridges, bridges that inspire us and stir our imagination. The souls of men have been poured into their creation. Beyond the steel and the stone, the timber and the concrete, there is one priceless ingredient—the spirit of consecration. And that includes the qualities of vision, devotion, inspiration, and integrity. This spirit is eloquently expressed in the words of John Ruskin:

> Therefore when we build let us think that we build forever. Let it not be for present delight, nor for present use alone. Let it be such work as our descendants will thank us for: and let us think, as we lay stone upon stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor and wrought substance of them, "See, this our fathers did for us."

A bridge is not only a steppingstone of civilization—it is also a symbol of unity, the embodiment of the aspirations of humanity.

THE EDDINGTON PRINCIPLE

To find the constant, yet not measure light
Nor trace a comet in its starry course—
Forget the old equation, train the sight
Beyond beginning, to the source's source.
Add fact to fact, compound experiments
To reach the cosmic number, but to come,
Through qualitative thought that circumvents
Mere measurements, yet names the final sum.

To find man has been thinking in reverse:
Truth can be reached through theory alone—
At last to grasp the laws of universe
Without so much as weighing of a stone—
To leap to fundamentals and to find
The purest constant with the plastic mind!

MAE WINKLER GOODMAN

Cleveland, Ohio

Men and Elephants in America

LUDWELL H. JOHNSON, III

Ludwell Johnson attended public school in Richmond, Virginia. After his discharge from the U. S. Navy, he entered The Johns Hopkins University, majoring in American history, with work in anthropology under George F. Carter. At present he is studying in the Hopkins graduate school Department of History.

THE years since the Wisconsin glaciation began its slow retreat to the north have witnessed the disappearance of many species of New World fauna. Perhaps the most spectacular of these were the American elephants—woolly mammoth, mastodon, imperial mammoth—animals that have for centuries provoked much interest and speculation. Why did the elephant, not to mention the giant beaver, the horse, the camel, the dire wolf, and many more, become extinct in the Americas? When did the last survivors of the great herds die? Did the Indians hunt elephants? These and many other questions have often been asked, and, although many are still without satisfactory answers, the fund of information is steadily increasing.

Discoveries of associations of human and proboscidean remains are by no means uncommon. As of 1950, MacGowan listed no less than twenty-seven.[1] Finds of this nature have in fact been known for more than a hundred years, but the inertia of scientific opinion in the twentieth century has until very recently offered considerable resistance to the idea that man and mammoth were contemporaneous in America. For example, Clark Wissler, in the 1917 edition of *The American Indian,* stated positively that "the contemporaneity of man and the mammoth has not been established for North America."[2] The tenacity of this idea was so great that as late as 1951 an attempt was made by Hugo Gross to explain away the obvious implication of various man-mammoth associations. Take, for instance, Gross' discussion of Albert Koch's 1838 discovery in Gasconade County, Missouri, of charred mastodon bones together with projectile points and large stones weighing up to twenty-five pounds.[3]

> Koch took for granted that ancient hunters killed this mastodon mired in the clayey mud of the river bottom, tried to destroy him by fire, and at last stoned and speared him (for large stones were found upon and within the ash layer). Curiously, no one questioned this absurd conception of ancient hunters having annihilated such a bulk of flesh in this fashion. . . . It is suggested that later Indians found a practically complete skeleton near their camp, perhaps exposed by a spring freshet, and for superstitious reasons tried to destroy it by burning and then hurling rocks at it. The same reasoning may account for the famous purported association of a partly burned mastodon skeleton and numerous potsherds at Alangasi, Ecuador. Two projectile points found near the Richmond mastodon in Indiana are very similar to those found by Koch and may also have become accidentally associated with a mastodon killed much earlier by carnivores. . . .[4]

With regard to the "absurd conception" of killing elephants with large stones, Henry Fairfield Osborn, eminent American paleontologist, some years ago reported the "discovery of giant killing flints by Dr. Carl Absolon of the University of Prague and the Museum of Brunn, one of the most distinguished archaeologists of central Europe, is therefore a revelation . . . of the killing methods employed, whereby the animals were driven into great pits and then felled by giant stones. . . ."[5] At least such practices were not absurd in Europe. Second, the Koch projectile points are similar not only to those found near the Richmond mastodon but also to points found in Jacob's Cavern, where the celebrated mastodon carving was unearthed.[4] In the third place, it is an unlikely coincidence that Indians in Missouri and Ecuador (and possibly in South Carolina)[3] would use virtually identical methods in their alleged superstitious attempts to destroy these defunct elephants.

Perhaps the most devastating technique used to discredit discoveries which run counter to the general climate of anthropological opinion is to imply that the find in question is a hoax. The venerable brotherhood of the politely raised eyebrow could with a single skeptical glance strike a live mammoth dead in his tracks. And, in justice to the conservatives, it must be admitted that anthropology has had its share of fakes and wild theories, and that legitimate archaeological evidence can often be misleading if not interpreted with extreme care. There was, for example, a site in California

where excavation revealed an Indian stone mortar below a mastodon jawbone—the implication being that elephants survived until very late in that area. Below the mortar, however, a cast-iron Dutch oven was turned up, showing the association to be accidental and of no chronological significance.[6] It is not difficult to imagine the theories that would have been born if digging had been stopped before the oven was found. Unfortunately, in the effort to avoid rushing to unjustified conclusions, scientific opinion, or at least a large part of it, swung to the opposite extreme of narrow dogmatism and used such incidents as that just described to discount any discoveries that called for a revision of existing beliefs.

There can no longer be any reasonable doubt that man and elephant coexisted in America. A century's accumulated evidence has recently received a decisive addition which established this fact beyond question. In the vicinity of Tepexpan, Mexico, one of many excavations in that area brought to light the bones of an imperial mammoth with projectile points in the ribs and with stone knives and scrapers close by. First estimates placed the age of these remains at from 11,000 to 16,000 years,[7] but later carbon 14 datings give an age of about 18,000 years. Still later estimates based on soil data strongly indicate that this mammoth met its end well back in Wisconsin time, during the last glaciation.

With regard to the final disappearance of New World elephants, it is not yet possible to give a reliable time estimate. Unlike the Tepexpan find, few man-mammoth sites have yielded enough evidence to give even a minimum age. The result has been a great deal of speculation and a very wide range of guesses as to the date of extinction. At one extreme are such statements as that of the great paleontologist William Berryman Scott, who believed that "had the first Spanish discoverers of America penetrated into the interior, it is quite possible that they might have met with the living mammoth."[8] He based this opinion, at least in part, on the occurrence of elephant bones under only a few inches of peat.[4] The Eastern archaic projectile points found at the Koch, Richmond, and Jacob's Cavern sites have been assigned an age of 5000 years,[4] but this is a tentative and uncertain dating. A. L. Kroeber believed that most of or all the species now extinct, including the elephants, had died out by the period 10,000–5000 B. C.[9] A majority of anthropologists would probably subscribe to this statement.

Probably it is safe to say that American Proboscidea have been extinct for a minimum of 3000 years. Culture levels within that span of time, to which fairly accurate dates can be given, have been consistently barren of man-elephant associations; the longer this lack remains, the more certain it will be that the elephant did not survive into these later archaeological horizons. The discovery of bones under only inches of peat does not justify Scott's inference of late survival; it is possible for soil forms and levels to remain remarkably stable for many thousands of years.

One of the most intriguing sidelights on the question of man and elephant in America is the controversial "mastodon" bone found at Jacob's Cavern, Pineville, Missouri. Carvings in elephant bone, which obviously could have been executed long after the animals were extinct, are not uncommon.[10] But the crude drawing made on the bone of a Virginia deer found in Jacob's Cavern is, if authentic, the only American eyewitness sketch of an extinct species of elephant—the sole, feeble counterpart to the virile mammoths of Magdalenian art. Figure 1 shows the primitive nature of the carving.

FIG. 1. The "mastodon" bone.[11]

The authenticity of this bone was vigorously challenged by N. C. Nelson, who felt that the carving was a recent forgery.[12] His detailed allegations were answered fully and, it must be said, convincingly by V. C. Allison, who subjected the bone to a number of exhaustive tests.[11, 13] A priori, it would seem that anyone attempting to perpetrate a fraud would have made his drawing a little more obviously elephantine than the crude sketch illustrated here.[14] There seems no substantial reason to doubt its legitimacy. Allowing this, however, it is always possible to say that this primitive figure was never intended to represent an elephant, and that any such resemblance is a matter of coincidence. In view of the extreme simplicity of the design, it must always be open to question, but certainly the probabilities of the case are in the other direction. The age of the bone can never be positively determined, since it was not found *in situ*. On the basis of his chemical investigations (the bone was heavily mineralized), Allison conjectured a mini-

mum age of 14,000 years, but at best this is only a guess.[11]

II

Elephant remains and Indian legends relating to them have provoked interest and inquiry from early colonial times. Possibly the earliest account of such inquiry comes from Cotton Mather (1663–1728), famous Congregational divine, who told of an Ohio Indian story about the giant bones. The animals were described as having once been abundant. They fed upon the leaves of the lime (basswood) tree and when they slept they did not lie down, but *leaned against a tree.*[15] Pierre François Xavier de Charlevoix (1682–1761), Jesuit traveler and writer, recounted a most remarkable Algonkian legend: *"Il a, disent-ils, les jambes si hautes que huit pieds de neiges ne l'embarrassent point: sa peau est à l'épreuve de toutes sortes d'armes, & il a une manière de bras, qui lui sort de l'épaule, & dont il se sert, comme nous faisons de notres."*[15] The Indians called this beast the "grand original;" usually "original" referred to a moose. This is, to say the least, a singular tale. What else could the "sort of arm which comes out of his shoulder" be except an elephant's trunk? What but the sight of a living elephant could have inspired such an account?

Thomas Jefferson was deeply interested in paleontology, geology, and, in fact, in all phases of natural history; his was an omnivorous mind. He was especially fascinated by the elephant bones that were being found even in that period, and in the Indian stories concerning them. In his *Notes on Virginia* Jefferson transcribes such a story:

> Our quadrupeds have been mostly described by Linnaeus and Mons. de Buffon. Of these, the Mammoth, or big buffalo, as called by the Indians, must certainly have been the largest. Their tradition is, that he was carnivorous, and still exists in the northern parts of America. A delegation of warriors from the Delaware tribe having visited the governor of Virginia, during the revolution, on matters of business, after these had been discussed and settled in council, the governor asked them some questions relevant to their country, and among others, what they knew or had heard of the animal whose bones were found at the Saltlicks on the Ohio. Their chief speaker immediately put himself into an attitude of oratory, and with a pomp suited to what he conceived the elevation of his subject, informed him that it was a tradition handed down from their fathers, "That in ancient times a herd of these tremendous animals came to the big-bone licks, and began an universal destruction of the bear, deer, elks, buffaloes, and other animals which had been created for the use of the Indians: that the Great Man above, looking down and seeing this, was so enraged that he seized his lightning, descended on the earth, seated himself on a neighboring mountain, on a rock of which his seat and the print of his feet are still to be seen, and hurled his bolts among them till the whole were slaughtered, except the big bull, who presenting his forehead to the shafts, shook them off as they fell; but missing one at length, it wounded him in the side; whereon, springing round, he bounded over the Ohio, over the Wabash, the Illinois, and finally over the great lakes, where he is living at this day."[16, 17]

Writing on the same general subject, Jefferson continues:

> It is well known that on the Ohio, and in many parts of America further north, tusks, grinders, and skeletons of unparalleled magnitude, are found in great numbers, some lying on the surface of the earth, and some a little below it. A Mr. Stanley, taken prisoner by the Indians near the mouth of the Tanissee, relates, that, after being transferred through several tribes, from one to another, he was at length carried over the mountains west of the Missouri to a river which runs westwardly: that these bones abounded there; that the natives described to him the animal to which they belonged as still existing in the northern parts of their country; from which description he judged it to be an elephant. Bones of the same kind have lately been found, some feet below the surface of the earth, in salines opened on the North Holston, a branch of the Tanissee, about the latitude of 36½° north. From the accounts published in Europe, I suppose it to be decided, that these are of the same kind with those found in Siberia.[16]

Albert Koch published in 1841 an account of an Indian legend roughly similar to that related by Jefferson. It is an Osage tale.

> There was a time when the Indians paddled their canoes over the now extensive prairies of Missouri, and encamped or hunted on the bluffs. . . . That at a certain period many large and monstrous animals came from the eastward, along and up the Mississippi and Missouri rivers; upon which the animals which had previously occupied the country became very angry, and at last so enraged and infuriated, by reason of these intrusions, that the red man durst not venture out to hunt any more, and was consequently reduced to great distress. At this time a large number of these huge monsters assembled here, when a terrible battle ensued, in which many on both sides were killed, and the remainder resumed their march towards the setting sun.[8]

This story and that related by Jefferson are probably in large part "myths of observation"[15, 18]—efforts by the Indians to account for the existence of the great bones about which they had no real knowledge. On the other hand, Stanley's report indicates that some of the Western tribes may have retained traditional descriptions of the mammoth with considerable accuracy. It is interesting to note that William Berryman Scott wrote of

> a widely spread legend among the tribes of the Northwest British provinces, that their ancestors had built lake dwellings on piles like those of Switzerland, "to protect themselves against an animal which ravaged the country long, long ago. . . . I find the tradition identical among the Indians of the Suogualami and Peace Rivers, who have no connections with each other. . . ." So suggestive were these Indian tales that on some of the early maps of North America the mammoth is given as an inhabitant of Labrador.[18]

Strong, in his valuable article, reproduced a Naskapi account concerning a creature called Katcheetohuskw. The story is too long to be set down in full here, especially as the body of it is not particularly significant; the really important point is the Indians' description of the monster. "When asked to describe Katcheetohuskw, the informants said he was very large, had a big head, large ears and teeth, and *a long nose with which he hit people*" (italics supplied). "His tracks in the snow were described in their stories as large and round."[15] Strong did not believe, as some skeptics do, that this description was a result of leading questions asked by whites because, as he said, "the older Indians questioned were unanimous in declaring that such had always been the description of Katcheetohuskw so far as they had any knowledge."[15] Strong's interpretation of the story has been strongly questioned by several gentlemen who maintain that in its true translation Katcheetohuskw (other spellings are put forward) denotes a mythical bear, a stiff-legged, hairless, anthropophagous being endowed with supernatural powers.[19–21] Their contention, although certainly impressive, does not come to grips with the Indians' picture of the beast. A bear may well be said to have a big head and large teeth. But by no coruscation of the imagination can he be said to have "a long nose with which he hits people."

A Penobscot "Snowy Owl" legend mentioned by Strong is dealt with more at length in a later article by F. G. Speck, one of those who disagreed with Strong's interpretation of Katcheetohuskw. The following is an abstract from this tale:

> Snowy Owl proceeded then to find the monsters which he had seen before. He went to where the animals had their "yards." He cut certain trees, where he had observed the monsters were accustomed to lean for rest at night, almost through, so that when the monsters would lean on them they would break. When the creatures went to rest at night leaning against the trees, they fell upon the sharpened stumps when the top bent over and broke, and could not get up again; and Snowy Owl shot them all.[19]

It is an amazing fact that in the Sixth Book of Caesar's *Gallic Wars* there appears an almost identical account of an animal of the German forests which the Roman called an elk.

> In outward form and in the parti-coloration of its skin, this has much in common with the Italian wild goat, though in build it is slightly heavier. Its horns are mutilated and its legs are marked by an absence of any natural protuberance or joint; it never lies down to rest, and if accidentally cast, is powerless to recover its position or to raise itself from the ground. Its lairs are the trunks of trees, leaning against which, with its body slightly out of the perpendicular, it will go off to sleep. On discovering from their tracks any of these animals' favorite haunts, the huntsmen either undermine all the trees of the immediate neighborhood, or else cut them through just far enough to leave them apparently still firmly standing. The elks then return and lean against these as usual, and their weight proving too much for the weakened trunks, they and their supports come crashing to the ground.[22]

It is submitted that this was not a description of a living animal, as Caesar believed, but that Caesar's informant was relating a very old German tradition about the mammoth. At first glance it might seem rather difficult to make an elephant out of an animal which is favorably compared to a goat. It can be pointed out, however, that a method of hunting is by its nature more easily described and understood than is the animal itself, and that Caesar may very well have got a clear comprehension of the former and a distorted picture of the latter. Little imagination is required to see that the curling tusks of a mammoth may, in the course of a double translation, have become the "mutilated horns" ascribed by Caesar to the so-called elks. Moreover, no animal at all comparable to a goat in size could be hunted in such a way as that used by the Germans (and by Snowy Owl).

Sir Thomas Browne, in his *Common Errors*, had the following to say about the elephant:

> The first shall be of the Elephant; whereof there generally passeth an Opinion, it hath no joynts; and this absurdity is seconded with another, that being unable to lie down, it sleepeth against a Tree; which, the Hunters observing, do saw almost asunder; whereon, the Beast relying, by the fall of the Tree, falls also down it self, and is able to rise no more. Which conceit, is not the daughter of later times, but an old and gray-headed Error, even in the daies of Aristotle. . . .[23]

Here again is the same tradition, and this time it is explicitly applied to elephants. Bertha L. Loomis, in "The Elephant in the Literature and Art of Greece and Rome," gives an ancient method of capture which "consisted of noting a tree in the forest against which one of the giant beasts was wont to lean for support when he slept, hew into it from the opposite side and await his return. His mammoth bulk would fell the tree and carry him down with it to a position from which he was unable to rise."[24] As early as the fifth century B. C., Ctesias, Greek physician and historian, stated that since the legs of an elephant were jointless it has to sleep in a standing position, "tied to a tree."[24] Aelian (d. 222) was most surprised at the dancing of the trained Roman elephants, for he also believed that their legs had no joints.[25] Philes, Matthew Paris, Shakespeare, and John Donne all fell into the same error.[25] The persistence of this belief was such that its currency continued to the nineteenth and twentieth centuries, and doubtless many people could be found today who subscribe

to this ancient error. For example, Charles John Andersson wrote in 1873 that " it is a commonly received opinion . . . that the elephant always keeps standing, or reclining, it may be against a tree or rock; or, as regards Southern Africa, against one of those gigantic ant-hills one there so frequently meets with. . . ."[26, 27] Captain Francis A. Dickinson, a big-game hunter, believed that the elephant, if he ever lay flat on the ground, would be unable to get up.[28] By 1923, however, George A. Chamberlain reported that modern hunters had exploded the hoary assertion that elephants rarely lie down, although it is unusual for them to do so.[29]

The essential elements in this complex of traditions are: (1) stiff, jointless legs; (2) the inability to rise from a prone position; (3) always, as a consequence, maintainenance of a standing position; (4) the habit of leaning against a tree when sleeping; (5) hunting the animals by weakening the trees against which they sleep. All these elements are present in the Penobscot story of Snowy Owl, in Caesar's account of the German "elk," in Browne's *Common Errors,* and, to a lesser degree, in the method of hunting as reported by Bertha Loomis. Mather's Ohio Indian legend and the story of the stiff-legged Katcheetohuskw fall into the same pattern. The only conclusion to be drawn is that all these traditions and beliefs, American as well as European, are derived from a common source—elephants.

To return to the Penobscot Snowy Owl tale, Speck remarked that the story is rather explicit as to the physical appearance of the creatures killed by the Owl, especially with regard to their shaggy hair. "In another narrative the beast is described as having teeth long enough to pierce seven hunters, a lip as long as 'seven paces,' and an unconquerable strength. . . ."[19] Only one animal could fit this description.

Strong gives a number of other, less graphic, legends that may be briefly itemized. (1) *Ojibwa and Iroquois:* a vague belief concerning a large animal which could crush trees in its path; (2) *Algonkian:* the "Great Moose," which used a fifth leg rooted between its shoulders to prepare its bed; (3) *Alabama and Koasati:* insist on translating "man-eater" (*Atipa tcoba*) as "elephant;" (4) *Chitimacha:* "A long time ago a being with a long nose came out of the ocean. . . . It would root up trees with its nose to get at persons who sought refuge in the branches, and people lived on scaffolds to get away from it. . . . When the elephant was seen it was thought to be the same creature. . . ." (5) *Atakapa of Louisiana:* one of the earliest records of this tribe "tells of their tradition that a beast of enormous size perished in one of several nearby watercourses. Duralde, the chronicler, adds that the subsequent discovery of an elephant skeleton in Carancro bayou seemed to realize this tradition."[15]

In this same general stream of inquiry, Marian W. Smith ran across a possible example of the sabre-toothed tiger in American folk memory.

While giving incidental vocabulary, a Puyallup informant named one too many members of the local cat family: cougar, panther, mountain lion, and a fourth, lion. The Salish term for the latter, he explained, was currently used for the maned lion seen in the zoos, etc., but had previously referred to a much larger animal with enormous teeth. In his boyhood, people had told of the ferocious attacks of this cat on children and adults, although actual encounters, he insisted, had ceased "long, long" before.[30]

III

Needless to say, these stories, legends, and traditions have been vigorously and frequently challenged as frauds, distortions, and misinterpretations. It is a case of a few rotten apples spoiling the entire barrel. And it cannot be denied that there have indeed been some very rotten apples. Mammoth bones and ivory have been known since well before the beginning of the Christian Era and have given rise to many fantastic myths.[31] Skeletons of unoffending Proboscidea have been reconstructed as the human remains of ninteen-foot giants. They have been called the remnants of Pallas, son of Evander, of King Teutobochus, of the Cimbri, of Og, king of Basan, and of the elephant Haroun-al-Raschid sent to Charlemagne. A mammoth tooth was once believed to have come straight from the mouth of St. Christopher, and a great thigh bone was exhibited in triumphant procession as a saint's arm. Others believed that they had found proof of the giants mentioned in Genesis.[1, 25]

Not all the fraudulent myths and accounts are of such ancient vintage. Such a tale was born in the latter part of the nineteenth century when C. H. Townsend, naturalist of the U. S. Fish Commission, in the course of a voyage along the coast of Alaska, touched at Cape Prince of Wales. Some natives of the vicinty came on board with a number of elephant bones and tusks; they were asked by Townsend if any of the animals were yet living. The Eskimos answered that they were not and inquired whether the white men had ever seen them or knew what they looked like. Townsend showed them a picture of the well-known St. Petersburg skeleton and then, relying on his recollection of a restoration he had seen, drew a sketch of the mammoth in the flesh. These pictures were taken ashore,

and it was only a question of time before they were widely circulated and examined. Rumors of still-living mammoths began to filter down through the wilderness, and these reports were taken up by the newspapers with results that can easily be imagined. Eskimos were found who could give excellent descriptions of the defunct elephants.[32]

Such incidents can go far toward discrediting all elephant legends, regardless of intrinsic merit. Nevertheless, it is manifestly unjust to tar all the mammoth traditions with the same fraudulent brush. But tarred they have been. In the vanguard of the attack is Loren C. Eiseley, who plunges into the midst of the legendary proboscideans and lays about him with a grim zestfulness. And as an authority on the historiography of the subject he has, in a series of articles,[33–37] come near to putting the whole herd to rout.

Eiseley's main line of approach consists in characterizing the legends as misleading distortions which sprang naturally from the intellectual climate of the late eighteenth century and the early nineteenth:

> It must be remembered that the eighteenth century and the beginning years of the nineteenth marked the rise of intense zoological interest among the intelligentsia of the New and Old Worlds. The great eighteenth century forerunners of Darwin—Buffon, Cuvier, and others—were beginning to approach, with much hesitancy and many misgivings, the problem of specific change. Others fought back with vigor. America, with its strange animals, its mysterious bones, and a human race unaccounted for in Biblical terms, had contributed to those uneasy stirrings. A science was being born. The specialist bewailing the lack of interest in his subject today may be surprised to learn that mammoth, sloth, and other bones were taken back to Europe and exhibited for a fee in polite circles. We find Jefferson advising one lad that he may make a fortune in this way.
>
> Men crossed the Atlantic to pursue the subject. Indians were questioned. Jefferson's legend was plagiarized and repeated. But one must keep the background of all this in mind: in spite of intense stirrings of curiosity, religious conservatism held the field—would hold it until Darwin. Men knew but little of the science which was to become geology. They sought explanations of the mammoth in terms of Biblical quotations. They talked of Behemoth. The millennial swing of the glacial pendulum was unknown. Here were bones. If the beast had existed, he must still exist. Jefferson, for example, certainly no religious fanatic, comments almost piously, "such is the economy of nature that no instance can be produced of her having permitted any one race of her animals to become extinct; of her having formed any link in her great work so weak as to be broken."
>
> As for the Indians, involved in their own vast animal mythology, it is quite likely that they responded to these myriads of questions with elaboration and desire to please.[34]

Eiseley goes on to amplify his position, remarking that the Indians "found no difficulty in suggesting that these creatures for which the white man seemed to be searching lay farther on in the heart of the wilderness, or 'across the lakes.'"[34] He traces, theoretically, the elephant myths to other outside sources, to tales of the African elephant brought by the slaves, to Russian ivory hunters in Alaska, to the late survival of the modern elephant in China.[34]

At first glance, this is a plausible hypothesis, and there probably have been stories which sprang from such sources. But the whole body of legends cannot be dismissed merely on the basis of generalities. These traditions are spread over an immense extent of territory, from coast to coast, from Canada to the Gulf. It would have taken a veritable army of men, asking leading questions, artificially to produce such an effect. The fact that widely separated tribes have similar traditions shows that the ultimate inspiration must have been direct contact with some species of extinct elephants. To say that the closely related Penobscot, Neskapi, and Ohio legends, which have counterparts in European literature, are post-Columbian in origin, it is necessary to assume that all three tribes were told similar stories by whites and that they then obligingly incorporated them in their folklore. Moreover, the Ohio legend was reported by Cotton Mather, who himself believed that mammoth bones were those of Biblical giants, not elephants. Charlevoix, who certainly was not trying to build up a case for American elephants, made his observations in a period before there could have been any substantial adulteration of native traditions. And if the Naskapi description of Katcheetohuskw was a foreign introduction, the Indians themselves were completely unaware of it. Most of the stories, in the verisimilitude of their detail, ring true.

In short, although it is not difficult to disbelieve one tradition, or two, or even three, the cumulative effect of all the available stories is irresistibly persuasive. That there have been misinterpretations, distortions, leading questions, and outright inventions cannot be denied. But when all due allowance has been made for these, there remains a solid foundation of genuine folk memories of the elephant that refuses to be explained away.

IV

Archaeology has proved that the American Indian hunted and killed elephants; it has also strongly indicated that these elephants have been extinct for several thousand years. This means that the traditions of the Indians recalling these animals have retained their historical validity for great

stretches of time. Exactly how long, it is impossible to say: probably the minimum is three thousand years; the maximum may be ten thousand or more. If some Indian traditions have remained historical for so many years, undoubtedly traditions of other races and peoples have also. Direct historical record of the past is usually thought of as extending no farther back in time than the beginning of writing, but, once it has been demonstrated that very ancient folk tales may have a high factual content, the sources available to the historian and anthropologist are increased tremendously. This field of research holds great possibilities for increasing man's knowledge of the past.

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ELTONIAN PYRAMID

A
M a n
A t e s e a l
Speared from a herd
Feeding on codfish and flounder
Schooling in cold Atlantic Ocean water
Where these fishes foraged on the bottom
Preying on numerous snails, crustaceans, and echinoderms
Which fed in turn upon abundant stocks of bivalve and annelid.
The shellfish had filtered from gallons of water detritus and plankton
Containing countless copepods, ciliates, bacteria, and algae, including diatoms,
All of which build link by link, level by level, an ecologic principle—the Eltonian pyramid.

Kent, Ohio — Ralph W. Dexter

Occupational Hazards in Microbiology

ROBERT M. PIKE and S. EDWARD SULKIN

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DURING the coming year approximately sixty-five laboratory workers in the United States will become ill as a result of infection acquired in laboratories concerned with various aspects of microbiology. One or two of these may die. At least this is to be expected on the basis of past experience.

One does not read far in medical history before learning of those who have died of the infectious diseases which they studied. The Peruvian medical student Carrión died of Oroya fever in 1886 after inoculating himself with the blood of a patient suffering from verrugas in an attempt to learn more about the latter disease. Unexpectedly, his drastic experiment showed that the two diseases were due to the same agent, now known as *Bartonella bacilliformis.* Since Kolletschka, associate of Semmelweis, contracted fatal septicemia while performing an autospy on a woman dead of childbed fever, numerous physicians have acquired infections, some fatal, while making post-mortem examinations. The dramatic experiments of the Walter Reed Commission at the beginning of the present century resulted in the transmission of yellow fever to Carrol and Dean, who voluntarily exposed themselves to the bites of mosquitoes that had previously bitten patients with yellow fever. They recovered, but Lazear, who was bitten accidentally, died of yellow fever. More than twenty-five years later this same disease was responsible for the deaths of Stokes, Guilett, Noguchi, and Young, who went to Africa to seek the disease agent transmitted by the mosquito. Because of the development of effective immunization and improvement in techniques, those who have worked with the yellow fever virus in recent years have been protected from the risks taken by their predecessors.

Rickettsial diseases have also taken their toll. The American investigator Ricketts, for whom these microorganisms were named, died of typhus fever while studying that disease in Mexico in 1910. Ricketts had previously shown that wood ticks transmitted Rocky Mountain spotted fever, a rickettsial disease which, in the years from 1921 to 1927, was to cause the death of McClintic, Gettinger, Cowan, and Kerlee. Bacot, likewise, while studying the infectivity of louse excreta in Egypt in 1922, contracted fatal typhus fever.

Between 1905 and 1918 other fatal laboratory-acquired infections were recorded in the case of relapsing fever, undulant fever, plague, glanders, and meningitis. Eventually certain disease agents came to be recognized as being especially hazardous to the microbiologist. The virus of psittacosis caused infection in 44 per cent of the personnel of a research laboratory at the National Institutes of Health in 1930. The 74 known instances of brucellosis among laboratory workers were summarized in 1941, and a number of additional cases have occurred since that time. Reported instances of laboratory-acquired typhoid fever, tularemia, Q fever, and coccidioidomycosis indicated that the agents of these diseases were among those most likely to infect those studying them. In 1949 Sulkin and Pike collected records of laboratory infections caused by viruses alone and found 222 cases, of which 21 had terminated fatally.

Some microbiologists spend a lifetime in the laboratory without contracting any of the diseases they study. Others are less fortunate and become infected more than once. The all-time record is held by Edward Francis, eminent investigator at the National Institutes of Health, who during a period of twenty-seven years contracted dengue

fever, tularemia, undulant fever, psittacosis, and relapsing fever as a result of his laboratory work. Two other bacteriologists who have worked at the same institution—George McCoy and Charles Armstrong—have each had three laboratory-acquired diseases, and others, too numerous to mention, are known to have acquired more than one.

When a new disease agent is discovered, there is a good chance that it will infect some of the investigators who study it in the laboratory. Only recently that has happened with *Rickettsia akari,* the cause of rickettsialpox, which was first recognized in New York City in 1946. Already there have been four cases of rickettsialpox acquired in the laboratory. The most recent additions to the virus group, the Coxsackie viruses, were first described in 1948. Although their relation to human disease is not yet completely understood, on at least six occasions they have infected the persons working with them.

Sometimes an infection acquired by a laboratory worker is the first instance of that disease known to occur. Thus, the name of the young investigator Brebner is associated with the "B virus" infection from which he died in New York City in 1932. His illness followed the bite of a laboratory monkey that was to be used in research in poliomyelitis. Since then only two other B virus infections have been recorded, both contracted from laboratory monkeys. The virus that causes louping ill, an encephalitis of sheep, was discovered in 1930. Within a few years six laboratory workers contracted the disease, but it was not until 1948 that the first human infection caused by this virus was recognized outside the laboratory. Q fever was first observed in Australia, but the rickettsia which causes it was first isolated in the United States, from ticks at the Rocky Mountain Laboratory of the Public Health Service, in 1938. After visiting this laboratory Rolla Dyer, then of the Public Health Service, developed Q fever. His infection was the first recognized case in this country. More than 60 cases of Q fever that were due to laboratory-propagated strains of this microorganism had occurred in the United States before the disease was found to occur naturally among packing house workers.

As the science of microbiology expanded, more and more persons became engaged in work that required close contact with the agents of infectious disease. The risk of infection was experienced not only by those looking for previously unrecognized causes of disease but also by technicians performing routine examinations in clinical and public health laboratories, by animal caretakers, and by those concerned with cleaning laboratory apparatus. Unless some unusual circumstances were involved, instances of laboratory infection were no longer reported in the medical literature. Consequently, there was no way of knowing how frequently laboratory infections were occurring, what types of work were most dangerous, or where the greatest efforts should be made to establish safety measures. One way of gaining more complete information regarding the occurrence of laboratory infections was to ask as many laboratories as possible about such infections. To this end the National Medical Advisory Council requested that a survey be made. This was done in 1950 by Sulkin and Pike under the sponsorship of the National Institutes of Health. Nearly 5000 laboratories in the United States were asked about infections that had occurred during the previous twenty years. From the data thus assembled—although it was necessarily incomplete—information was obtained regarding 1334 cases of infection arising presumably in the laboratory.

All kinds of infectious disease agents were represented in these illnesses (Fig. 1), although some were more frequently involved than others. Deaths occurred in all categories except in those due to parasites. The frequency with which the various kinds of agents were involved, however, is not necessarily a reflection of the risk involved in working with them. One important contributing factor to this distribution is the number of persons under risk. For example, a larger number of workers in a greater variety of laboratories are exposed to various kinds of pathogenic bacteria than to viruses or

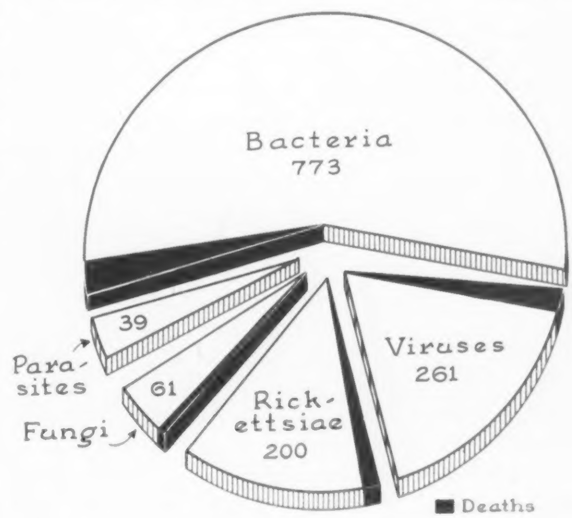


Fig. 1. Agents responsible for 1334 instances of laboratory infection. Black segments indicate fatal cases.

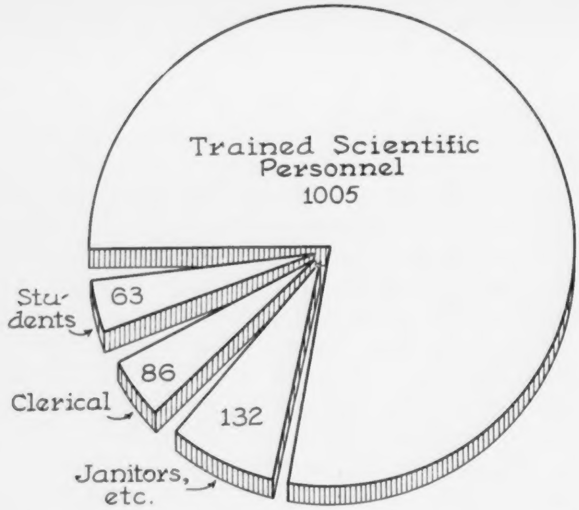


FIG. 2. Types of personnel involved in 1286 instances of laboratory infection.

rickettsiae. On the other hand, a greater proportion of viral and rickettsial infections have been fatal.

Tuberculosis, which ranks second among the bacterial diseases presumed to be of laboratory origin, has been a matter of special concern because of the large numbers of persons who handle tuberculous materials in clinical, research, and teaching institutions and because of the severity and prolonged course of the disease. Since the onset is insidious, and since there are numerous opportunities for acquiring the disease outside the laboratory, it is usually impossible to trace the source to any particular incident that might have resulted in infection. Except for those instances in which the individual is infected through the skin, as in an accidental puncture wound, only circumstantial evidence points to the origin of infection in the laboratory. Infection can also take place through the alimentary tract, but the respiratory route is more common. Many current techniques used in tubercle bacillus research are directed toward obtaining highly dispersed suspensions of the bacilli, thus making possible atmospheric contamination with minute particles, which may penetrate to the deepest recesses of the lungs. The potential hazard of tuberculosis is considered so great that several medical schools no longer permit classes to study materials containing living tubercle bacilli.

Laboratory infections are not confined to the scientific personnel most closely associated with the infectious agents (Fig. 2). Although professional and technical workers, research assistants, and graduate students experienced about three fourths of the illnesses, office workers, janitors, and dishwashers became infected as a result of activities in the laboratories with which they were associated. Students were infrequently involved, although the number in courses dealing with infectious disease is estimated to be greater than the number of persons in any other group concerned.

Several factors contribute to the low rate among students. The student's contact with disease-producing agents is less extensive than that of the research worker. Instructors usually recognize the hazards and either use the less infectious agents as teaching material or insist upon adequate precautions.

The circumstances leading to cases of infectious hepatitis (jaundice) in the laboratory are unique in that the material from which they arise is often obtained from apparently well persons. Attention was first attracted to this form of hepatitis when it was observed to occur in individuals who had received injections of blood plasma or biologic preparations containing serum. The virus that causes this disease may be present in the blood for several months without symptoms, with the result that any blood specimen from an apparently healthy individual may contain the virus. In the laboratory, persons who examine blood, even though their work may not be directly related to infectious disease, and those who clean the glassware containing the blood, are in danger of contracting hepatitis. In recent years more laboratory infections have been caused by this agent than by any other virus.

If laboratory infections are to be prevented it is necessary to know how they are caused. Often, it is known only that an individual had been working with the particular agent (Fig. 3) or that he had

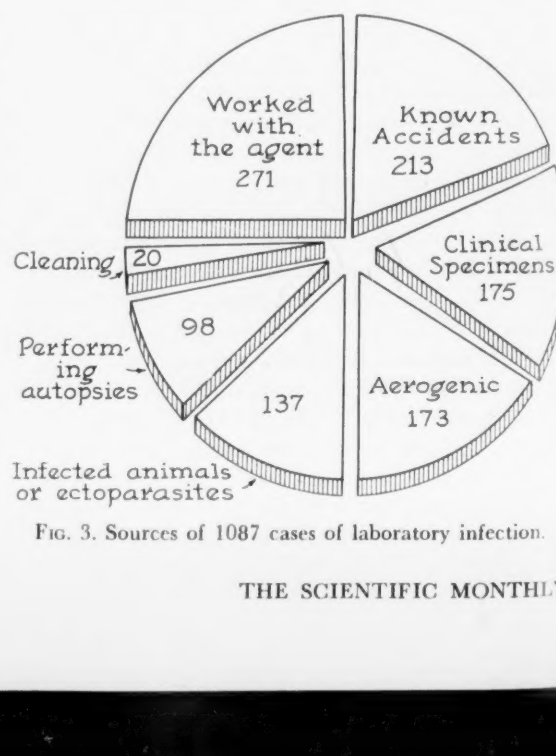


FIG. 3. Sources of 1087 cases of laboratory infection.

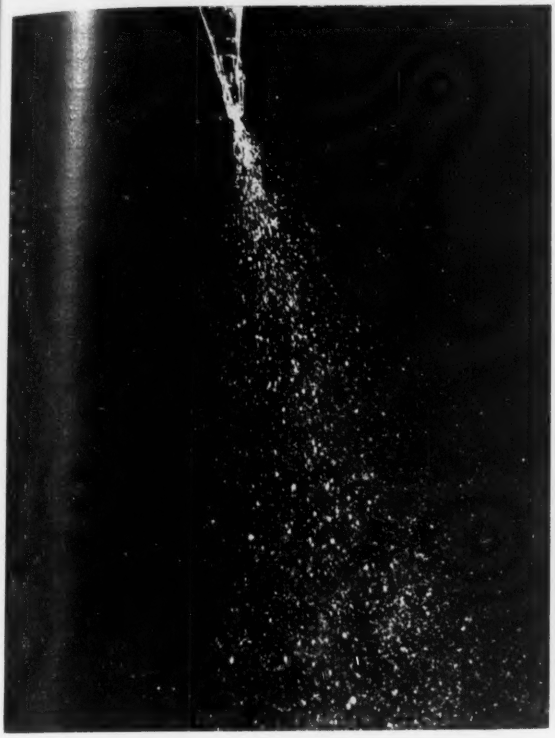


Fig. 4. Spray resulting when the last drop is blown from a pipette. This shows how the environment may be contaminated without the knowledge of the worker. (Johansson and Ferris. *J. Infectious Diseases,* **78**; reprinted by permission.)

been in contact with infected animals or ectoparasites. In other situations, it is known that the atmosphere of the laboratory had become contaminated, resulting in aerogenic transmission. This potential source of infection has been more fully appreciated since bacteriologists at Camp Detrick, Maryland, have designed atmospheric sampling devices which show that such common and simple procedures as removing stoppers and pipetting fluids may produce aerosols near the laboratory bench (Fig. 4). In only one fifth of all laboratory infections can the source be traced to an accident. Some types of accidents tend to be repeated: Infectious material is drawn into the mouth through a pipette; the skin is accidentally pricked with a hypodermic neddle, or the needle may separate from the syringe during animal inoculation; or, again, the test tube is broken or its contents are spilled.

The tendency of some infectious disease agents to cause infections of laboratory personnel has attracted the attention of those concerned with defense against possible biological warfare. One of the qualifications for success in biological warfare is ease of transmission of the disease-producing agent.

Fig. 5. Using a hood to protect the worker and the environment from contamination with highly infectious material. The interior of the chamber can be sterilized by ultraviolet light. The stack contains an incinerator to destroy disease agents in the exhausted air.

In addition to revealing what diseases may be transmitted under artificial conditions, a study of labo-

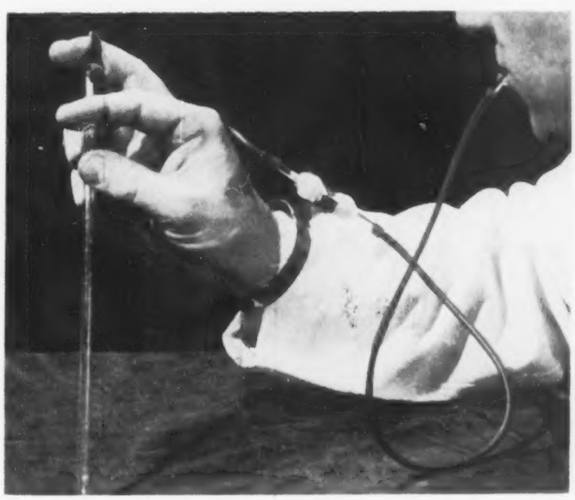


Fig. 6. Pipetting device designed at the Biological Laboratories, Camp Detrick. The trap in the tubing prevents contents of pipette from being accidentally sucked into the mouth. (A. G. Wedum. *J. Lab. Clin. Med.,* **35**; reprinted by permission.)

ratory infections also shows that under these circumstances there are frequent exceptions to the natural mode of transmission. Under natural conditions most infectious diseases are transmitted in some characteristic way. Some, like typhoid fever, reach the host by way of contaminated food and water. Others, including typhus fever, encephalitis, and yellow fever, are transmitted by lice, fleas, mites, or mosquitoes. In still others, the agents are discharged from the respiratory tract of one individual and directly or indirectly reach the respiratory tract of the susceptible victim through the atmosphere. In many laboratory infections the pathway of transmission is atmospheric, although this may not be characteristic of the naturally occurring disease. This mode of transmission has accounted for at least one case of fatal typhoid fever. Encephalomyelitis and typhus fever have resulted repeatedly in the laboratory from inhaling the agents of these diseases, although the naturally occurring infections are transmitted by arthropod vectors.

There are two approaches to the protection of laboratory workers. One is the development and use of safety devices; the other is active immunization. Both have certain limitations. Safety devices include hoods or cabinets in which highly infectious material is handled to prevent possible aerosols from reaching the operator or the atmosphere of the room (Fig. 5). Several types of mechanically operated pipettes are now available, which obviate the danger of drawing infectious material into the mouth (Fig. 6). Animal inoculation chambers have been designed to protect the worker, and the use of rubber gloves may sometimes eliminate the hazards to those who clean glassware. Precautions recommended in common manipulations are illustrated in Figures 7, 8, and 9. Employment of such measures is often inconvenient and time-consuming, however. The precautions that may have to be taken are well illustrated in the case of Q fever, which involved many laboratory workers during the first few years of study. In at least one laboratory where this agent is being handled extensively, procedures likely to produce infectious aerosols are avoided, infected animals are housed in separate quarters, triethylene glycol aerosols are maintained in workrooms and animal houses to help disinfect the atmosphere, and in addition all personnel are immunized with vaccine. The result has been the virtual elimination of Q fever infections in this laboratory.

Laboratory workers should be immunized to the agents with which they work whenever effective immunization procedures are available. Although immunization may not offer complete protection,

FIG. 7. The worker wears a plastic mask and cotton gown while loading a syringe in preparation for inoculation of mice. Contaminated glassware is discarded into pan for prompt sterilization by autoclaving. (J. E. Smadel. *Am. J. Pub. Health*, **41**; reprinted by permission.)

FIG. 8. When infected tissues are homogenized in a Waring blendor, removal of the lid may liberate a hazardous aerosol. The apparatus here has been modified to permit removal of contents by means of a needle and syringe. (J. E. Smadel. *Am. J. Pub. Health,* **41**; reprinted by permission.)

FIG. 9. In performing an autopsy on a small animal, precautions are taken to wrap carcass in wax paper for incineration and to sterilize glassware in conveniently located autoclave. (J. E. Smadel. *Am. J. Pub. Health,* **41**; reprinted by permission.)

disease that does occur in immunized individuals tends to be less serious. Immunizations against typhoid fever and smallpox have been practiced for years in the general population. Effective vaccines are also available for typhus fever, Rocky Mountain spotted fever, Q fever, several forms of encephalomyelitis, and yellow fever. Although the risk of infection in this latter group is not great enough to warrant general immunization, laboratory personnel working with the agents of these diseases should receive this protection. There is as yet, however, no means of immunization against poliomyelitis, fungus diseases, and some of the bacterial diseases.

Recent interest in the prevention of laboratory infections has resulted in the establishment by the American Public Health Association of a committee to study the occurrence of such infections, to attempt to determine their causes, and to recommend means of eliminating the hazards that exist. As in other fields of activity, occupational hazards are being recognized in infectious disease laboratories, and steps are being taken to control them.

Arid Lands and Plant Research

W. GORDON WHALEY

W. Gordon Whaley went from the Department of Agriculture in 1946 to the University of Texas, where he is professor of botany, chairman of the Botanical Laboratories, and director of the Plant Research Institute—Clayton Foundation for Research projects. Since 1946 he has also spent some time studying botanical developments in England and Sweden. The charming drawings are by his wife, Clare Y. Whaley, who also illustrated Dr. Whaley's book, Biology for Everyone, *and the recent* Texas Range Grasses, *by Benjamin Carroll Tharp, reviewed in* The Scientific Monthly *last month.*

DEFINITION of the potentialities of the desert and arid lands and the development of means of realizing these potentialities have long been matters of interest to many small groups of people. The events of the past several years and those we can anticipate with some certainty during the next several years make the propositions of increasing general interest.

The United States still has a rapidly growing population. We are faced, in addition, with the necessity for assuming great international responsibility involving, among other considerations, furnishing many products of our land to other peoples. We have before us a real threat of another great war. These factors require that we gain and maintain an increasingly high level of agricultural productivity. Quite possibly, within the next several years we may have to attain a much higher level than we have yet achieved. On the other hand, we have problems of lowered soil fertility and, for various reasons, the necessity of withdrawing some lands from agricultural production. These and other factors will tend, in time, to come into conflict with attempts to increase agricultural production.

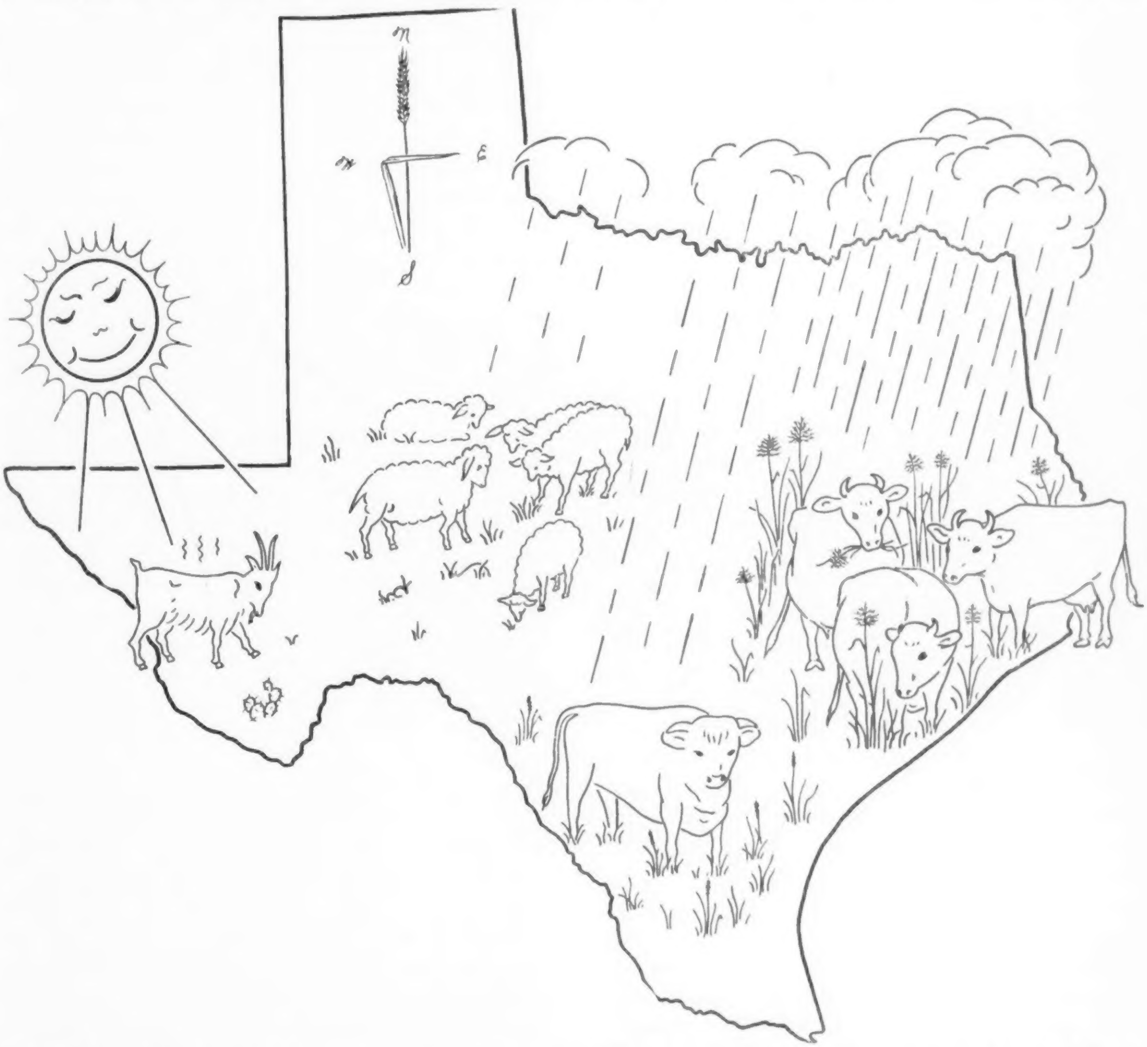
A measure of productivity given to the now largely unproductive arid lands would certainly be a safety factor in any attempt to meet heightened demands for products of the land. If any considerable measure of productivity could be given to arid lands now unproductive these lands might, in the long run, well come to mean the difference between success and failure.

Any hope that great arid regions can be made highly productive without the manipulation of water is most certainly a false hope. Water is too much a key substance in the metabolism of organisms to permit us to suppose for a moment that we can develop masses of vegetation in its absence. The manipulation of water involves the ancient practice of irrigation and now, possibly, rain-making and the utilization of desalted sea water on arid lands situated close enough to coasts. The limitations of irrigation for a great part of our arid regions are obvious. The factors of availability of water, constancy of supply, and distribution distances are likely to prove insurmountable in many instances. As yet too little is known about the potentialities of rain-making to evaluate its usefulness for the solution of arid land problems. It seems in order, however, to call attention to the vast difference between the problem of making rain fall as an emergency measure for the temporary alleviation of dry conditions and the problem of increasing, with consistency, the average annual rainfall of a naturally dry region. No means have yet been found to make rain fall from a dry atmosphere. If economical methods for desalting sea water are ultimately developed, a formidable distribution problem will still exist.

Much attention has been given to the utilization of native desert plants. Where special substances in limited demand are involved, such utilization is an important consideration, and we should do all that is possible to study the nature of the substances available and their possible usefulness as a means of contributing to over-all productivity. We ought not to lose sight, however, of the fact that the plant productivity of the arid lands is simply too low for us to hope that these lands will ever naturally produce any considerable amount of bulk substances. There are too few plants, and they grow much too slowly, to provide substantial supplements to the mass production of our great

farmland regions. The establishment of imported plants in our arid regions may also offer a means of making available limited supplies of certain special substances, and this possibility ought to be subject to continuing investigation. We must, however, face the fact that the world's flora is now well known and that the likelihood of discovering a plant that will grow satisfactorily in such regions as those with which we are concerned, and produce in quantity substances of considerable usefulness, is at best slight.

There is another approach which I believe presents some real possibility for increasing the productivity of certain semiarid lands if developed in conjunction with what we may be able to do over the years to improve the water distribution picture. Except where there are sharp mountain divides, the semiarid and arid lands are set apart from lands with adequate moisture by transition regions rather than by sharp barriers. These transition zones are sometimes quite extensive. The state of Texas provides an excellent example of such a transition. The average rainfall in Houston is 44.84 inches; in San Antonio, 26.79 inches; and, in El Paso, 8.56 inches. The usefulness of the land for farming, or as range, decreases almost directly with the rainfall, although, of course, other factors are also important. Within these transition regions



The decreasing productivity per acre across the state of Texas is largely a reflection of decreasing rainfall, although, of course, soil differences and other factors are involved. Heightening the productivity of the regions with adequate rainfall is largely a matter of improved management, although, where the rainfall pattern is not consistent, selecting and breeding of grasses for greater drought resistance should help. In regions of less adequate rainfall, plant improvement can be expected to do much to increase productivity. Making the very low rainfall regions productive involves quite other problems.

there is a real possibility of increasing productivity by the selection and breeding of more drought-resistant and otherwise better-adapted plants. There are a number of desiderata involved.

One is the production of plants better able to stand the fairly regular periods of low rainfall which characterize certain of the marginal regions. Another is the production of plant varieties or strains with somewhat lowered general water requirements. Such plants might make it possible to extend the range of a species toward the truly arid regions. Still another is the production of plants capable of growing satisfactorily and staying green for somewhat longer periods when the regions in which they are growing become dry as part of a regular annual cycle. The extension of the green period for only a few weeks, or even a few days, would in many instances markedly increase productivity.

All these propositions involve attempts to increase (in degree) what is commonly spoken of as the drought resistance of plants which, although not characteristic of deserts, extend into the transition regions bordering our deserts. In discussing this question it is, unfortunately, possible only to indicate the problems involved and to suggest certain approaches, for, as yet, relatively little in the way of obtaining actual results has been accomplished.

We have a fair knowledge of the characteristics that set apart the plants ordinarily referred to as true xerophytes from mesophytes. Desert vegetation is characterized by plants variously modified for existence in arid regions. One group of such plants includes the cacti, which are modified so as to provide for the retention of considerable amounts of water. There are various other modifications—reduction in the number of stomata, heavily pubescent surfaces, extreme cutinization and other epidermal modifications, reduction in the amount of leaf surface, reduction in branching, shedding of leaves, and a considerable number of additional modifications which it can be assumed are related in one way or another to the ability of the plants to withstand desiccation.

A long series of investigations has indicated that the physiology of such plants differs from that of the mesophytes, although it is by no means clear just what the differences are. If we leave aside the cacti and other succulents with large water reserves, we find that the arid region plants are characterized, in general, by higher osmotic pressure values, a fact seemingly related to some fundamental differences in resistance to evaporation. In many instances, however, the drought-resistance characteristics of the native arid land vegetation are facultative characteristics rather than obligate ones. Put under conditions more favorable from the standpoint of available water, the plants will grow more satisfactorily and produce much more material in a given period of time. At any rate, the very characteristics that tend to adapt these plants to dry lands also limit their usefulness. Their form, composition, and relatively slow growth are all a part of their success in adaptation and equally as much a part of their limitations as useful plants. How much could be done in the way of selection and breeding to improve the usefulness of the true arid region plants, we do not know. This is a subject which, in association with continued attempts to discover uses for their known products for specific uses, should most definitely be pursued.

At the moment, however, it does not look as hopeful as the proposition of extending, by increasing drought resistance, certain elements of the more mesophytic vegetation of proved value. In this respect grasses and legumes seem to offer the greatest possibility for utilization of certain marginal lands. As a group, the grasses extend into the very arid lands. They combine a usefulness for forage with soil-holding capacity and other desirable characteristics. More and better-adapted legumes are a conspicuous need of all range lands.

Breeding grasses specifically for adaptability involves some difficulties that are a part of any project in plant breeding, and some that are characteristic of this specific problem. Grass flowers are small, difficult to emasculate, and otherwise hard to handle generally in breeding operations. It frequently takes an hour to do the work necessary to make a cross, and sometimes crosses cannot be made. Until recently the chromosome numbers of the grasses were incompletely known, and a good deal of time has been spent in trying to make biologically impossible crosses. We have counted in our own laboratories chromosome numbers of some 260 grass species, and these, together with those published elsewhere, now give us a fairly adequate picture of chromosome numbers. As a group, there is a considerable range of chromosome numbers, and there are many polyploid series. As would be expected in such a situation, there are reproductive abnormalities of various sorts. Cleistogamy often modifies the reproductive picture, and apomixis is a not uncommon characteristic. These and other considerations make it essential that we attempt to develop sufficiently the pattern of reproduction in the species with which we wish to work. Assuming, however, that we can accumulate enough knowledge to be able to proceed intelligently and with

The productivity of much rangeland in semiarid regions could be greatly increased by controlled grazing and by the development of drought-resistant grasses of higher nutritional value and more capacity to withstand the effects of grazing.

Better range cover for sheepland is a definite possibility. Because sheep are generally put on land that will not support cattle, and because the effects of their grazing are somewhat different from those of cattle grazing, the problems of producing better grasses for sheepland are different than those of producing better grasses for less arid cattle ranges.

In regions of very low rainfall the production of a plant cover that will withstand much grazing is unlikely. Many of these regions, however, contain plants that produce substances of value. On others, limited grazing is possible and can frequently be made profitable.

maximum efficiency in a grass-breeding program, there still remains the problem of what constitutes the drought resistance we are so anxious to enhance but of which so little is actually known.

The flowers of grasses are exceedingly small. The stamens and pistils are very delicate, and they are enclosed within structures that are often difficult to remove. Together, these factors make the crossing of grasses tedious and often exasperating. (Flower of purpletop grass, *Tridens flava*, ×60.)

We know, from natural distribution and experimental work already done, that certain grass species are much more drought-resistant than others, and that some of them have combined with drought resistance other features that make their use in the arid lands desirable. We have a fair indication, founded on a little experimental work, that there are strains with some degree of drought resistance among the more highly desirable borderland mesophytic grasses.

With these facts at hand, the exercise becomes one in selection and breeding, but it is an advanced exercise and it is much more easily talked about than performed. A considerable body of knowledge regarding the distribution of the grasses leads us clearly to the choice of species with some natural drought resistance. There is a similarly extensive body of knowledge pertaining to the palatability and nutritional value of the grasses. Some of this knowledge has been built up by experimental work; much of it is the result of the accumulation of the practical observations of ranchmen over a great many years.

Ideally, we should like to take a highly drought-resistant grass and a grass with great nutritional value and cross them, taking advantage of the outstanding characteristics of both and, perhaps, if the cross be wide enough, of hybrid vigor. If we can select grasses with the same chromosome numbers or mutliples of the same numbers and there are no other barriers, we have at least a good chance of making the cross.

Once the cross is made we have another problem. If the cross is not wide, we may get a vigorous F_1 hybrid, but further sexual reproduction of the F_1 hybrid will involve segregation and, most likely, the loss of favorable combinations of characteristics. If the cross is wide, there is probably a greater chance of the hybrid being sterile than of its being fertile.

Fortunately, we now have enough knowledge and command of enough techniques to do something about such hybrids. The characteristic of apomixis, which occurs frequently in the grasses, must, in any breeding program, often be looked upon as a nuisance of the first order, for if it is complete it precludes the possibility of using as breeding stocks the plants in which it occurs. In another respect it has, however, a great potentiality for usefulness. There is reason to believe that we can work the characteristic into hybrids. If we can get it into vigorous hybrids in combination with other desirable characteristics, there is no need for further concern about the possibility of segregation, for if the plant sets seed without sexual reproduction its progeny will remain constant. Such a use of apomixis, already worked out in *Parthenium* crosses, would appear to be a definite possibility in the grasses. There is always the additional possibility that vegetative reproduction can be utilized, but it is hardly conceivable that vegetative reproduction would represent a successful means of propagating plants for large areas of dry land.

Sterile hybrids can also be dealt with, at least in certain cases. Studies of species relationships have indicated that many species, or so-called species, are the result of hybridization followed by chromosome number doubling producing fertile plants. It would hardly be practicable to plan a breeding program and have to sit around and wait for the natural occurrence of chromosome doubling to produce fertile hybrids. Fortunately, by the application of colchicine or one of a number of related substances, we can, with relative ease, cause chromosome doubling to take place. By such techniques as these we have a better than fair chance of developing fertile grass hybrids that might be of great value in advancing high nutritional strains farther into semidrought and drought areas.

The breeding operations are, however, but one step in any practical program designed to achieve this objective. The sorting of resulting hybrids and their testing for adaptation to the regions in ques-

tion are equally important items. The development of so-called controlled-environment laboratories, in which specified predetermined growing conditions can be established at any time, provides a means of greatly accelerating adaptation tests.

One other technique needs mention with respect to grass-breeding potentialities. We have for years had at hand means of increasing mutation rates by radiation treatments. We now have, in addition, chemical mutagens. So far, such techniques have been applied mainly to rather classic experimental material. We have begun, with a certain amount of success, to apply some of them to native grasses. The induction of mutations by any technique involves, of course, the production of mutants which are, by and large, less well adapted to existing conditions than the wild stocks. There is, however, always a chance of producing a mutant with superior characteristics. Whether or not this is achieved, such mutations may have real usefulness in a breeding program because of their contribution to genetic knowledge of the species.

At present we have at hand sufficient information relating to the grasses on one hand and certain of the factors in the arid land picture on the other to make, with the application of techniques that have been worked out, progress of a sort and at a rate which fifteen or twenty years ago would have seemed utterly impossible. The grasses look like a good starting place. There is no reason to assume that we cannot also make essentially equivalent progress with other arid region plants.

No amount of research progress will ever solve the arid land problems, but improvements of the sort that now seem possible could, if coupled with much wiser handling of grazing on arid and semi-arid lands, do much to enhance the production potential of such lands.

ATLANTIC REEF CORALS TEASE ME OUT OF THOUGHT

Reading the story of abyssal depths
Far into night where searchlights do not go,
I was entranced to learn about Bermuda,
The place I seek to get away from snow
In February.

Its volcanic stage,
During the mystery of the Eocene,
Forty or so million years ago,
It sank below the surface of the sea,
Worn down by wave action, long and slow.

Further sinking, marine sediment
And limestone fell there in the Tertiary.

Then an atoll grew upon its bank;
All the diligent madrepores could carry

Until today: Bermuda rises cool,
Serene, wind-tossed above Atlantic's pool.

MERRILL MOORE

Boston, Massachusetts

College and University Research Resources

JOHN I. MATTILL

Mr. Mattill, after work at Carleton College and the State University of Iowa, became assistant director of the News Service of Massachusetts Institute of Technology, a position he still holds, in addition to being director of the Office of Publications. He was secretary of the Engineering College Research Council (1946–52) and this survey was made under Council auspices.

SINCE the beginning of the Korean War, colleges and universities have been under growing pressure to undertake new research enterprises. Federal defense agencies, especially, have sought to use these many facilities to help meet urgent national needs for research and development in a time of scientific manpower shortage.

The impact of this defense research effort has been a subject of wide concern in all educational institutions. But a national inventory of college and university research resources, completed in 1951 by the Engineering College Research Council, gives grounds for optimism.

It is true that, at some schools, research undertakings now appear to be so large that increases may endanger the teaching programs. However, on a national scale, there is a generous backlog of resources on college and university campuses. And the current requirements provide a remarkable opportunity to extend the benefits of research participation to many schools where they have never before been fully realized.

The problem, according to the Engineering College Research Council findings, is to achieve a broader and more equitable distribution of research undertakings—that is, to utilize a larger proportion of the available talents by finding and filling the holes in today's research pattern. By compiling the information that makes these openings evident, the Research Council has taken what the *Christian Science Monitor* called "a first step in correcting the serious shortage of research engineers and natural scientists."

The national survey project was undertaken by the Engineering College Research Council, a unit of the American Society for Engineering Education, at the suggestion and with the cooperation of the Department of Defense Research and Development Board. It was completed under the direction of the council's Committee on Relations with Military Research Agencies, of which A. F. Spilhaus, of the University of Minnesota, is chairman.* The first report of results was made by Dean Spilhaus at the 1951 annual meeting of the ASEE.[1]

To compile a national inventory of college and university research potential in engineering and science, the committee sought data from all four-year educational institutions on the numbers of faculty available, their present research commitments, and their special interests and qualifications. Despite its shortcomings, the questionnaire process was used by the committee to yield data suitable for mechanical processing within a strict time schedule.

Only 250 of the nation's 1000 four-year colleges and universities failed to contribute to the project. An informal review of the list of schools from which no replies were received suggests to the committee that "substantially all" the national potential for research in colleges and universities in the physical and engineering sciences has been reported.

Of the 750 schools replying, 513 listed personnel qualified for research in one or more of the physical and engineering sciences. The remaining 237 replied that their staffs were not active in any of these fields.

The totals from the 513 schools are shown in Table 1. Of nearly 25,000 faculty members reported, 20,000 are considered by their institutions to be qualified to perform research and only 12,700

* Members of the committee in addition to Dean Spilhaus were A. P. Colburn, University of Delaware; W. L. Everitt, University of Illinois; F. B. Farquharson, University of Washington; C. W. Good, University of Michigan; Paul E. Klopsteg, Northwestern University (now at the National Science Foundation); James S. Owens, Ohio State University (now with the Champion Spark Plug Company); J. R. Van Pelt, Montana School of Mines; and Eric A. Walker, Pennsylvania State College. Gerald A. Rosselot, Georgia Institute of Technology, was chairman of the Engineering College Research Council.

are now active in research. An average of 27 per cent of the time of faculty members reported is spent on research activities, and on a national average 45 per cent of this time is already being spent on defense research—studies sponsored by military agencies, the Atomic Energy Commission, or their industrial contractors.

Putting these figures another way [Dean Spilhaus has pointed out], of the 25,000 faculty members reported, one-half are active in research; these spent about one-half of their time in research, and one-half of this is devoted to military research. This means that one-eighth of the total college effort in these fields of engineering and the physical sciences is already devoted to defense research.[1]

Defense officials are known to hope for a further increase in the use of college and university research facilities, and industrial needs are also rapidly mounting.[2]

The Distribution of College Research

According to figures in the Research Council survey, nearly 40 per cent of the qualified scientists and engineers on American college faculties have no research in progress—and presumably are available for part-time studies. This group of 8000-odd teachers, if they become active in research on a one-third time basis, can add the equivalent of over 2700 full-time research workers to the national effort. They would increase by nearly one half the total contribution of colleges and universities.

Needless to say, these untapped research resources are not evenly distributed among all schools. Some institutions have traditionally accepted more research and have correspondingly lightened faculty teaching loads. The current emergency, combined with decreasing science and engineering enrollments, may make possible an extension of this pattern.

The Research and Development Board's interest in the project led the Research Council Committee to study first the distribution of defense research as revealed by survey questionnaires. No one was surprised to find federal defense research concentrated in a limited number of institutions.

One almost inevitable concomitant of government-supported research [said Joseph W. Barker in his 1951 *Annual Report* as president of Research Corporation] is that the government bureaus naturally seek out as contractors the "going concerns" in our educational and scientific institutions. The bigger and more famous the institution, the greater the pressure upon it to undertake more and more government-sponsored programs.[3]

TABLE 1

Summary of Personnel Reported in Scientific and Engineering Fields

	Total Number of Faculty and Full-Time Research Personnel	Number of (A) Considered Qualified to do Research	Number of (A) Now Engaged in Research	Number of Full-Time Research Workers to which (C) is Equivalent	Number of Research Workers in (D) now Engaged in Research for National Defense	Number of Graduate Students and Assistants now Engaged in Research	Number of Full-Time Research Workers to which (F) is Equivalent
	A	B	C	D	E	F	G
Aeronautical Engineering	652	597	437	289.7	236.8	566	284.2
Astronomy	279.3	246.8	159.8	105.3	39.5	225	130.1
Ceramics	216	200	156	108.8	42	215	122
Chemical Engineering	735.5	701.5	564	279.8	99.4	1699	807.4
Chemistry	3711	3319.5	2435.7	1316.1	506.2	6949	3468.4
Civil and Sanitary Engineering	1698	1429	654	313.6	112.1	936	443.1
Earth Sciences	1447.8	1322	964.2	452.4	172	2086	861.5
Electrical Engineering	1497	1237.5	601.5	288.1	219.1	1125	456.5
Electronics	1119.4	1032	625.6	387.2	313.8	1107	557.8
Food Technology	755.2	634	420	272.6	52.6	692	346.7
Industrial Engineering	535.5	421	173.5	77.1	14.1	352	108.9
Marine Engineering	78	71	35	17.7	12.5	24.2	13.9
Mathematics	3297.3	2261.8	1167.3	570	209.3	1496	640.7
Mechanical Engineering	2002.5	1660.5	716	327.1	150.5	1119.5	434.5
Mechanics	963.7	820.5	424.7	213.3	119.3	557.2	244.6
Metallurgical Engineering	487.5	458.5	349.2	187.6	131.7	757	387.7
Mining Engineering	135.5	128.5	82	44.4	11	129	50
Petroleum and Fuels Engineering	209	195	112	72.7	12.5	197.2	81.7
Physics	2628.4	2271.9	1546	866.6	609.3	3392	1562.1
Psychology and Human Resources	2432.4	2029.2	1242	554.7	227.1	3161.5	1141
Totals	24881	21037.2	12865.5	6744.8	3290.8	24785.6	12142.8

The survey figures show that fifteen colleges and universities† account for one half of the total faculty time spent on defense research throughout the nation, whereas these same institutions account for only 20.5 per cent of the total faculty and senior research staff members. In these fifteen "favored" schools, 75 per cent of the faculty are active in research, and 70 per cent of their research time is devoted to defense research. Only 15 per cent of those faculty members considered qualified for research remain without projects.

A combination of these figures shows that one third of the total effort in the physical and engineering sciences in these fifteen schools is devoted to defense research, compared to the average of one eighth in all schools.

The 498 educational institutions responsible for the other half of all defense research time have nearly 80 per cent of the faculty and 66 per cent of the graduate students reported. In these schools, an average of 45 per cent of the faculty members are active in research, but only 38 per cent of their research time is devoted to defense work. Only 55 per cent of those considered qualified have research opportunities.

Again to summarize, in the case of this large number of institutions, only one twelfth of the total faculty effort is in defense research, in contrast to the one-third figure found above.

The character of this research concentration is made still more obvious in an analysis of returns from a group of typical endowed liberal arts colleges. In these schools 60 per cent of teachers considered qualified are active in research, but less than 20 per cent of the research time is devoted to defense research. Only one thirty-second of the total faculty effort is in defense research. These statistics apply equally well to women's, men's, and coeducational colleges in this total group.

This concentration is especially associated with research projects under defense sponsorship. The "big fifteen," with half of the nation's defense research and only 20 per cent of the total faculty, account for just 20 per cent of the nondefense work. In some engineering fields (as will be noted below) defense and nondefense research crowd together at a few of many available institutions. But this tendency is reversed in some of the basic sciences, where federal contracts are a much greater share of the research in smaller schools than in large universities.

† The fifteen are: University of Michigan, University of California (Berkeley), Massachusetts Institute of Technology, University of Illinois, Pennsylvania State College, University of Minnesota, Cornell University, New York University, The Johns Hopkins University, Carnegie Institute of Technology, Georgia Institute of Technology, University of Texas, Columbia University, Ohio State University, and Princeton University.

TABLE 2

Distribution of College and University Research

	Percentage of all Research	Percentage of Defense Research
Chemistry	21.3	16.6
Physics	14	19.9
Mathematics	9.2	6.8
Earth Sciences	7.3	5.6
Electronics	6.3	10.2
Mechanical Engineering	5.3	4.9
Civil and Sanitary Engineering	5.1	3.7
Aeronautical Engineering	4.7	7.7
Electrical Engineering	4.6	7.2
Chemical Engineering	4.5	3.3
Food Technology	4.4	1.7
Mechanics	3.4	3.9
Metallurgical Engineering	3.0	4.3
Ceramics	1.8	1.4
Astronomy	1.7	1.3
Industrial Engineering	1.2	.5
Petroleum and Fuels Engineering	1.2	.4
Mining Engineering	.7	.3
Marine Engineering	.3	.4
Totals	100	100

Emphasis on Basic Sciences

These observations suggest that there are important variations in research distribution in the various physical and engineering sciences. The colleges and universities have traditionally emphasized the so-called basic sciences, represented in the Research Council survey by astronomy, chemistry, earth sciences, mathematics, and physics.‡ Almost half the faculty members covered by the survey are listed in these basic sciences—10,764 of the 22,449 total. And 54 per cent of the college and university research time is reported in these five areas (Table 2). One fifth of the national research total is in chemistry, and one third is in physics and chemistry combined.

Defense research shows a remarkably similar distribution: one fifth of the national total is in physics, one third in physics and chemistry, and one half in the five basic sciences. Seven of the applied engineering sciences—chemical engineering, food technology, ceramics, industrial engineering, marine engineering, petroleum and fuels engineering, and mining engineering——together contribute less than 10 per cent of the defense total. "This is convincing evidence," the Research Council

‡ The field of psychology and human resources was included in the survey at the suggestion of the Research and Development Board, since data were urgently needed for that area. The Research Council Committee has not attempted an analysis of results obtained in that field.

Committee says in its report, "that colleges and universities are maintaining emphasis on the fundamental sciences. Educational institutions must continue to resist temptations to undertake extensive assignments in applied research and development."[1]

Special conditions apply in some of the fields covered by the Engineering College Research Council inventory, and the following paragraphs summarize some of these special situations: §

Aeronautical Engineering stands as the No. 1 field in defense research demand (Table 3). Nearly three fourths of all qualified faculty in this field already have research under way, they spend substantially more than half-time on their studies, and 82 per cent of their work is defense research. Expansion to meet new research needs will be difficult. More than half of the aeronautics research is reported from only seven schools with only one third of the qualified faculty; here nearly two thirds of the total teaching and research effort goes to defense research. At 58 schools where no defense research is in progress, about 100 qualified aeronautical engineers remain available for part-time projects; this potential apparently represents the only reasonable addition to the universities' research contributions.

Astronomy, more than any other of the physical or engineering sciences, is centered in smaller educational institutions. Barely more than half the astronomers in the Research Council inventory are in 52 major universities; the others are at 76 colleges and smaller universities. In the larger schools, 84 per cent of those qualified have research in progress; in the smaller schools, only 40 per cent. Half the college research is under defense sponsorship, compared to only one third of that in the universities.

Ceramics shows the most critical research pinch found in the Research Council project. Only about 50 qualified faculty members remain without research under way. Five schools are doing 62 per cent of all ceramics research, and three of these are doing 60 per cent of all defense research. But at 27 schools no defense projects are under way, and at most of these there seems room for some new undertakings in ceramics. At institutions where defense studies have been located, these projects have absorbed most of the available talent.

Chemical Engineering is a research-conscious profession: eight out of ten faculty have research in progress, a proportion higher than in any other of the physical and engineering sciences. Only about 135 qualified chemical engineers have no research assignments, and chemical engineering research shows a broad and healthy national distribution. Defense projects are spread less widely; 45 per cent of the defense research time is reported by four schools which have only 13 per cent of all qualified faculty. At these schools, research takes two thirds of all faculty time; at other large universities the figure is from 50 per cent to 60 per cent, and among smaller schools it ranges commonly between 30 per cent and 50 per cent. The graduate student contribution to research in chemical engineering far outstrips that in any other engineering field.

Chemistry is at the top of the research list, with more faculty and graduate students—and more research under way—than in any other of the fields surveyed. The report shows 3319 qualified chemistry faculty, of whom only 884 are still without research projects. In the 104 larger universities reporting to the Research Council, only 11 per cent of the qualified teachers have no research in progress; at 93 smaller universities 38 per cent still await research opportunities, and in 279 liberal arts and teachers' colleges this figure rises to 52 per cent.

Civil and Sanitary Engineering follows a pattern typical also of *Electrical Engineering* and *Mechanical Engineering.* About half the qualified civil and

TABLE 3

USE OF COLLEGE AND UNIVERSITY RESEARCH RESOURCES

	Percentage of Qualified Faculty now in Research	Percentage of Research Time on Defense Work
Chemical Engineering	81	36
Ceramics	78	39
Metallurgical Engineering	76	70
Aeronautical Engineering	73	82
Chemistry	73	38
Earth Sciences	73	38
Physics	68	70
Food Technology	66	19
Astronomy	65	37
Mining Engineering	64	25
Electronics	61	81
Petroleum and Fuels Engineering	58	17
Mechanics	52	56
Mathematics	51	37
Marine Engineering	49	71
Electrical Engineering	48	76
Civil and Sanitary Engineering	48	76
Mechanical Engineering	43	48
Industrial Engineering	41	18

§ The full report of the survey, *University Research Potential,* identifies all schools reporting personnel and competencies. Copies are available from the office of the secretary, Engineering College Research Council, Pennsylvania State College, State College, Pa., at $1.00 each.

electrical engineers now have research in progress, and only one third of the mechanical engineers have these opportunities. In all three cases, however, government-sponsored research is concentrated at a few of many available engineering schools: half the civil engineering defense studies are at four schools, half of those in electrical engineering at eight schools, and half of those in mechanical engineering at five schools. New research opportunities will be welcome at all but these busiest institutions.

Earth Sciences, as defined for the Research Council survey, included geology, meteorology, and oceanography. Like most basic scientists, teachers of these subjects are busy with research: nearly three fourths of those considered qualified have studies under way. And, as usual, those in larger universities have greater research opportunities. Of the 1448 earth scientists, 931 are at 104 major universities, and 87 per cent of those qualified in this group have research projects under way. At 169 smaller schools, where 420 earth scientists are ready for research, only 53 per cent have studies in progress. Three quarters of the work in the smaller schools is under defense sponsorship, compared to less than one third in the major universities.

Electronics is an extreme case of research concentration. Over 80 per cent of today's electronics research is for defense needs, and 50 per cent of that work is at eight schools. Meanwhile, 150 other colleges and universities, with 425 faculty qualified in electronics, have no defense research commitments and presumably would welcome research opportunities. If all qualified faculty now available could be given resources for part-time projects, electronics research in colleges and universities could go up by more than 30 per cent.

Industrial Engineering stands close to the bottom of the research list, and very little work in this field comes under government defense sponsorship. The Research Council figures show 250 qualified industrial engineers who are available to take on new work. Of 100 schools reporting qualification in this field, eleven account for 47 per cent of the industrial engineering research total and for 75 per cent of all defense research. Obviously, those who seek new talent can expect to find most of it outside these eleven institutions.

Mathematics is a field somewhat different from others surveyed: many mathematicians are active in research by contributing to projects in other fields. Of the 2262 qualified mathematics faculty, 1243 are at 106 major universities. Of these nearly 70 per cent, at 90 schools, have research commitments—of which 40 per cent are for defense. The 1018 qualified teachers at colleges and smaller universities have far fewer research opportunities; only 30 per cent have any research in progress, and only 25 per cent of their work is for defense. Projects which depend on the participation of mathematicians can probably be planned at most schools but will be most welcome at smaller institutions.

Metallurgy shows a high research concentration and, at best, limited facilities for new projects. More than three fourths of the qualified metallurgy faculty are already active in research—a proportion exceeded only in chemical engineering and ceramics. These teachers are at 113 schools, only 31 of which have research contracts with government agencies. But at these 31 schools essentially all available teachers are involved in this defense work; it accounts for 95 per cent of all faculty research time, and 90 per cent of the qualified teachers have projects under way. At 82 other schools that are now without defense contracts, only 124 of 212 qualified metallurgists have any research opportunities.

Mining Engineering is the second smallest category in the Research Council survey.|| Only 64 per cent of the qualified faculty members listed are now engaged in research; percentagewise, there seems to be plenty of room for research expansion. Only 25 per cent of mining engineering research is for defense needs, and the mining industry, rather than federal defense agencies, will probably be the source for any future research increases.

Petroleum and Fuels Engineering is a newcomer among engineering sciences, and at many schools interest in this field is divided between chemical engineering and geology departments. Nevertheless, 65 colleges and universities report faculty qualified specifically in this area of applied science, and few more than half of these teachers have projects under way. Defense research accounts for only 17 per cent of these projects, the lowest proportion of any field surveyed.

Physics is second to chemistry in total college and university research effort, and physicists lead all others in their contributions to college defense research. Of the 2272 qualified physics faculty, 1460 are at 107 major universities which boast 82 per cent of all research and 91 per cent of all defense research. Only 35 per cent of the remaining 812 qualified teachers, at 338 smaller universities

|| *Marine Engineering* shows such small totals in the Research Council project that no analyses have been undertaken. The omission of even one institution—which would have relatively little effect were the totals larger—might entirely change whatever summary was made.

and colleges, have any research in progress at the present time.

The Tail that Wags the Dog

This recital of research statistics would seem a persuasive argument for decentralizing studies in science and engineering fields; it is an argument particularly appropriate for federal defense agencies, which maintain that there is a critical shortage of research talent to fulfill their greatly increased budgets.

But some reservations are necessary in this appearance of research concentration. Large universities, with many graduate students, have vastly more resources for advanced research. Graduate student thesis research involves faculty members, and their work with such students may record as "research time," although it is well within any definition of teaching duties.

Nor are all scientists equally well qualified. It is natural that contractors, both military and industrial, have turned first to the largest institutions, where talents in widest variety are available. On complicated problems there is often no substitute for the university's ability to bring faculty of many disciplines together on a single problem. Yet there must remain a large number of research projects that can be divided into packages suitable for small college laboratories.

The lack of certain specialized equipment may also limit the research commitments of small schools. But the Department of Defense appears principally concerned about scientific manpower shortages. Where manpower is available, the Research Council Committee believes that equipment necessary to implement research can be supplied. All agree that it is far better to move research equipment than to move research scientists, particularly when moving the scientists may endanger the supply of new science graduates.

So, despite some mitigating factors, the Engineering College Research Council submits its report on university research potential with the recommendation that efforts be made to expand and broaden research opportunities.

This suggestion is subject to the additional important reservation that the colleges' first purpose and responsibility are their teaching programs. At some institutions, where research is already a major part of the activity in many departments, or where general resources are most limited, increases in the research load must jeopardize teaching effectiveness. Research can become the tail that wags the dog; especially in a time of critical manpower needs, teaching needs strength —not competition.

But within sensible limits, and properly integrated into academic life, research can greatly benefit both teachers and students. Scientists need no itemized list of these gains. Today's critical needs provide a remarkable opportunity to broaden college and university research experience and so to capitalize more fully on its benefits.

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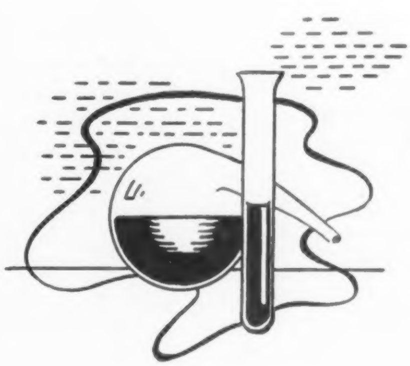


Chicken a la Laboratory

H. R. BIRD

A native of Wisconsin, Dr. Bird received his Ph.D. (in biochemistry) at the University of Wisconsin in 1938, after which he was associate professor of poultry nutrition at the University of Maryland until 1944. He has been at the Department of Agriculture's Bureau of Animal Industry, Beltsville, Maryland, ever since, in charge of poultry nutrition investigations until 1948 and of poultry investigations from 1948 up to the present time.

TODAY's chicken is a made-to-order bird. We do not know what characteristics of the Indian jungle fowl permitted men to shape his bodily structure, reproductive cycles, and nutritional habits so effectively. We do know that the twentieth-century descendants of the ancient patriarchs of the Indian jungle come in 59 breeds and 175 varieties recognized by the American Standard of Perfection, that some of them lay approximately 360 eggs per year instead of one or a few clutches, and that in the United States they annually consume about 1.5 billion dollars' worth of commercially manufactured feed that probably would have been unrecognizable to their remote ancestors.

Among the earliest experiments on the physiology of digestion were those performed by Reaumur on chickens and reported in 1750. The first experimentally produced vitamin deficiency in any animal was thiamin deficiency in chickens, described by Eijkman in 1897. When hybrid corn showed what heterosis could do for grain production, it was to the chicken that geneticists turned to see what could be accomplished in animal production by crossing inbred lines. Clearly, the chicken has proved to be adaptable to the purposes of the research worker as well as to those of the fancier and the food producer.

Since the chicken is an excellent experimental animal as well as the basis of a 4-billion-dollar industry, one would expect to find it used in a great variety of experiments, ranging from those designed to solve the problems of the industry to those designed to solve all sorts of problems in biology, biochemistry, physiology, and genetics. The distinction between so-called fundamental research and so-called applied research becomes so thin at times that the man who starts out to solve a fundamental problem in biology may find the poultry industry looking over his shoulder to see if he may not be about to turn up something of immediate and practical use.

For obvious reasons, the poultry research program in the Animal Husbandry Division of the Bureau of Animal Industry of the USDA must be planned to solve problems of the poultry industry. This necessity does not exclude fundamental research as we understand it. C. A. Elvehjem told the 121st national meeting of the American Chemical Society, "In our search for solutions to practical problems we may be stimulated to find some of our most basic concepts." Every industry problem has a basis in fundamental science and requires fundamental research to provide a really satisfactory answer. Thus, when it was found some years ago that replacement of animal protein supplements with soybean oil meal resulted in failure of growth and reproduction of chickens, a practical answer would have consisted of the empirical development of a diet using the maximum level of soybean oil meal and the minimum of animal products. The real solution, which is still incomplete, requires elucidation of the previously unknown dietary requirements that are not satisfied by soybean oil meal. Efforts toward this solution have contributed materially in the past few years to our knowledge of the distribution and biological properties of vitamin B_{12}.

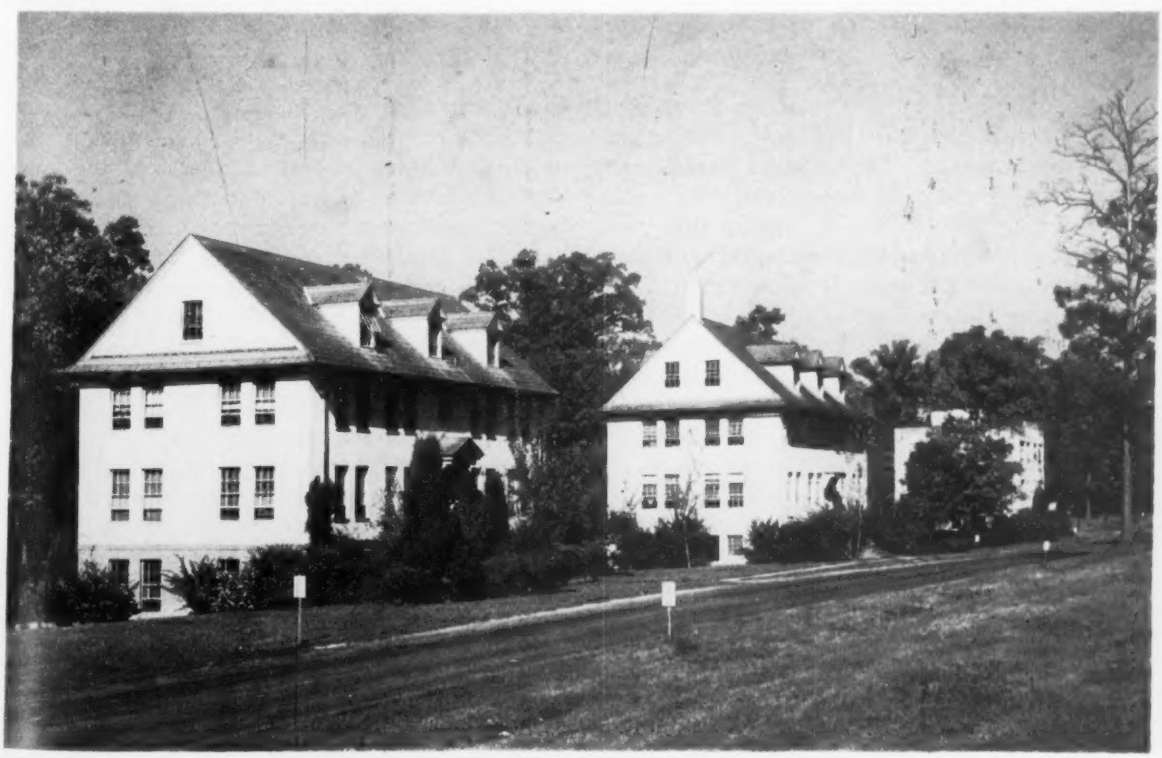
A practical solution of the problem of getting maximum egg production would seem to consist of determining the optimal day length, feeding schedule, and other environmental factors. The real solution requires knowledge of all the dietary and hormonal factors that influence egg production.

The poultry research program of the Animal Husbandry Division is centered at Beltsville, Maryland. The laboratory buildings are located at the approximate center of a 160-acre poultry farm that has housing facilities for approximately 8000 mature chickens, 1500 mature turkeys, 13,000 growing chickens, and 2500 growing turkeys. The fields of research are genetics, nutrition, physiology of reproduction, and poultry products. In addition to the establishment at Beltsville, the division oper-

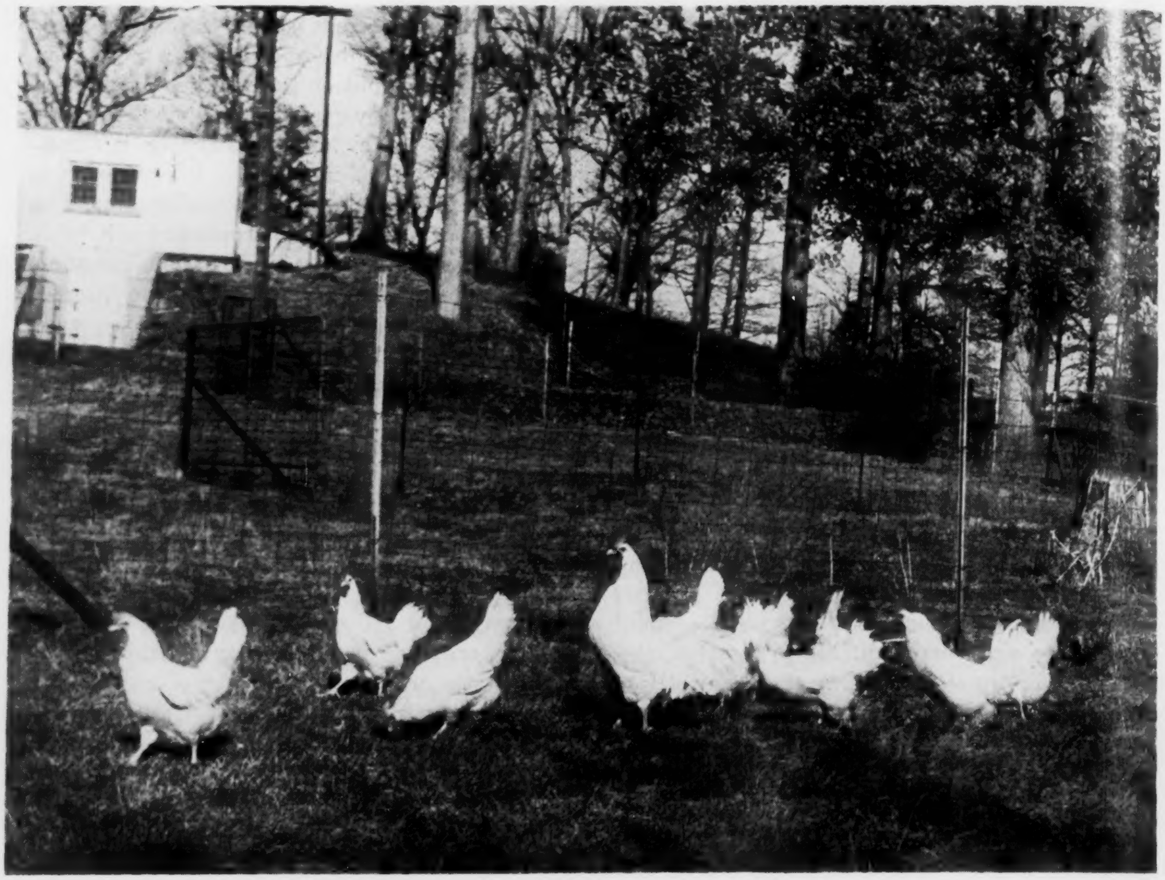
ates a station at Lafayette, Indiana, primarily for the testing of inbred lines of chickens, and a station at Glendale, Arizona, where nutrition and management problems are studied in a semiarid environment; also, it cooperates with the Pathological Division of the bureau in the operation of a laboratory at East Lansing, Michigan, for the study of lymphomatosis of chickens.

Although today's chicken is made to order, it is being subjected to still further tailoring by geneticists with a view to producing an even better chicken tomorrow. Rate of egg production is not a highly heritable characteristic. Like often begets unlike with respect to egg-laying capability. The selection of breeding birds on the basis of their own individual performance is therefore an uncertain business. Better results are obtained by progeny testing and family selection. These expressions mean just what they say—selection not of high-producing individuals but of high-producing families. There is another breeding method that is especially useful for characteristics of low heritability; namely, crossbreeding. The number of genes that control rate and persistency of egg production is quite large, and the hens with high production rates are those that have a suitable combination of genes. A high proportion of the individuals resulting from some crosses of different breeds have a "favorable" combination of genes for this and for other production factors. This phenomenon is called heterosis. Upon being questioned, any geneticist will gladly provide an unsubstantiated hypothesis to explain it. Crossing inbred lines of different breeds is a special type of crossbreeding and is called incrossbreeding. The resulting progeny are called incrossbreds, or hybrids. Since the individuals of an inbred line are more uniform than those of outbred stocks, the heterosis resulting from incrossbreeding is somewhat more predictable than that resulting from crossbreeding.

Crossbreeding and incrossbreeding are being studied at Beltsville as possible methods of increasing egg production. Some of the Rhode Island Reds now being used in these studies are the result of a breeding program involving brother-sister matings through 10 generations. Each individual in the present generation has one father and one mother, even as you and I. If, however, he were able to trace his ancestry back 10 generations, he would still find only one male and one female ancestor, whereas you or I would find 512 of each. White Leghorns have also been inbred for seven generations. The outbred stocks from which the inbred lines were derived have been maintained, and the methods of progeny testing and family selection



Three of the four laboratory buildings of the Poultry Section.



Breeding pen of outbred White Leghorns.

have been applied to both inbred and outbred stocks in order to increase egg production to the greatest extent possible. The results of several years of crossbreeding and incrossbreeding of these stocks are typified by the 1950–51 figures. In that year, average egg production of the outbred Rhode Island Reds was 222 and of the outbred White Leghorns was 211. Average egg production of the female progeny of outbred Leghorn males mated with outbred Red females was 253, a considerable improvement over either outbred stock. The female progeny of the reciprocal cross laid only 215 eggs, and thus were no better than the outbred stock. The Leghorn × Red cross has been consistently better than the Red × Leghorn cross, for reasons thus far unknown.

Incrossbred female progeny of inbred Leghorn fathers and inbred Red mothers laid 271 eggs during the year, somewhat more than the comparable crossbred birds. The daughters of inbred Red fathers and inbred Leghorn mothers laid only 231 eggs.

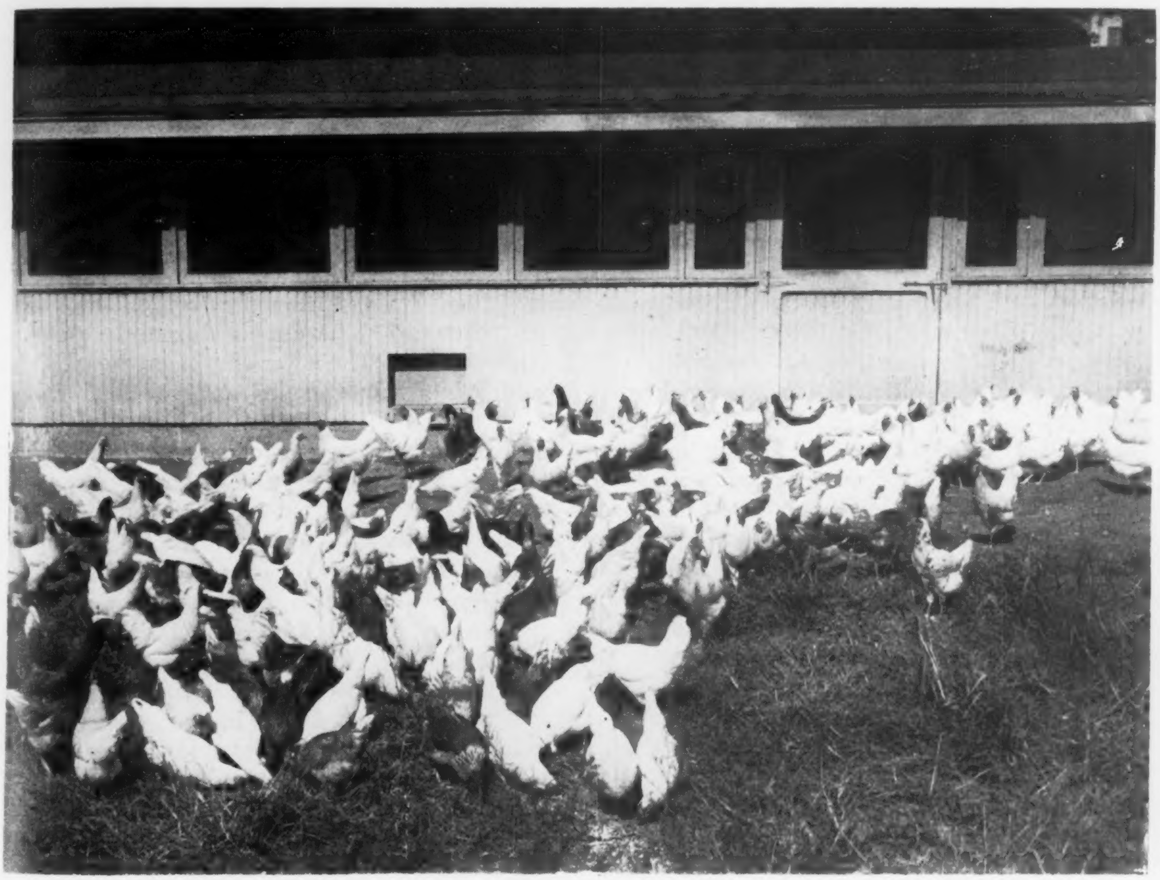
One would be entirely too hasty if he drew from these results a general conclusion that crossing outbred birds resulted in a significant increase in egg production almost as great as that resulting from incrossing. Many crosses of outbred stocks have been made without increasing egg production. As a matter of fact, one cannot cross any two inbred lines with certainty of an increase in production. Two lines must be found that complement each other. Once found, two such inbred lines have an advantage in that they maintain their identity and uniformity to a greater degree than do outbred stocks. In the present work consistent results over a three-year period have been obtained by crossing outbred Leghorns and outbred Reds. These results show that outbred stocks of sufficient uniformity for this purpose were maintained by family selection. The resulting crossbreds did not lay quite as many eggs as incrossbreds, but they were much more economical to produce.

Quality as well as quantity of eggs is important to producers and consumers. It was shown at Beltsville for the first time that inheritance determines the tendency to produce strong or weak shells, few

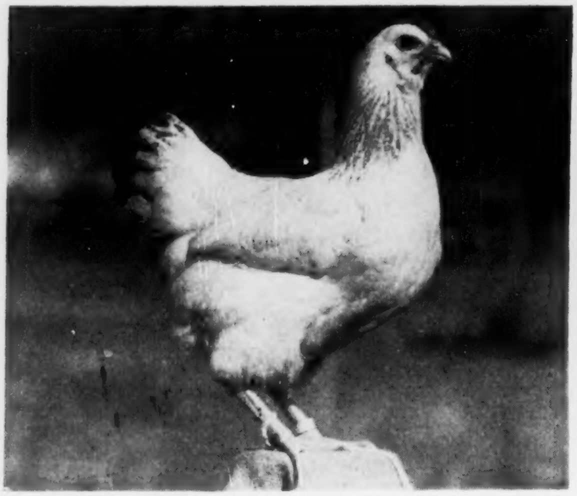
or many blood spots, and much or little thick albumen. A high percentage of thick albumen is desirable because it makes the egg "stand up" well after breaking. An egg with little thick albumen is a watery egg.

The experiments on thick albumen showed that inheritance governed not only the percentage of thick albumen in the fresh egg but also the ability of the thick albumen to withstand high temperature. A line of birds has been developed which lays eggs that can be held at 100° F for two weeks without becoming watery. When broken after holding at this high temperature, these eggs still appear like fresh eggs.

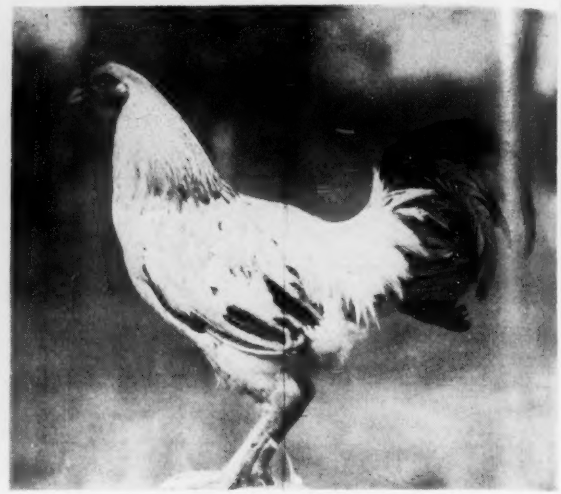
As a by-product of the research on inheritance of egg quality characteristics, a series of important observations has been made of the effect of Newcastle disease, or pneumoencephalitis, on egg quality. On two occasions this virus disease was an unwelcome factor in the research program. There were two outbreaks, about a year apart, in 1948 and 1949. Because of high mortality, each outbreak necessitated discontinuance of numerous experiments on chicks and complicated the interpretation of studies of egg production by causing temporary cessation of production and by severely impairing shell quality when production was resumed. The effects on production and shell quality had been established previously by field observations and were known to be transient. Purely by chance some pens of birds in the study of inheritance of egg quality characteristics escaped infection, whereas other comparable pens had the disease. As part of the experiment on inheritance the eggs of these birds were examined for percentage of thick albumen. This study brought to light the astonishing fact that 12 months after apparently complete recovery from the disease, watery eggs with a low percentage of thick albumen were still being produced. Fortunately, the uninfected birds of similar inheritance were available as controls. Subsequently it was found that vaccination with live virus after pullets had started to lay resulted in similar permanent damage to egg quality. Vaccination at three months of age, well before the beginning of egg production, had no effect on egg quality.



Flock of White Leghorn × Rhode Island Red crossbreeds.



Silver Cornish female.



Silver Cornish male.

Chickens are being tailored not only for egg production but also for meat production. The ideal broiler chicken would grow rapidly and efficiently, feather rapidly, be light in color or at least have light-colored pin feathers, and have a wide breast, heavy drumsticks, and high rate of egg production, fertility, and hatchability. The New Hampshire meets most of these requirements, but its body conformation is not ideal, and some of the fastest growing strains do not lay as well as they might.

In developing a new variety, the use of New Hampshire stock was purposely avoided in order that the new variety would be suitable for crossing with New Hampshires to produce crossbred broiler chicks. The new variety, called the Silver Cornish, was produced by crossing Brooksville Columbians with Dark Cornish, mating the crossbred progeny among themselves, selecting for desirable utility qualities and for Silver, or Columbian, feather pattern and then backcrossing Silver males to Dark Cornish females. Because of sex linkage the female progeny bred true for silver color and were added to the Silver Cornish. The Brooksville Columbians were developed originally at Beltsville and at Brooksville, Florida, from Rhode Island Red, White Wyandotte, and Light Sussex stock. The new Silver Cornish variety appears to have great possibilities for commercial broiler production because it compares favorably with the New Hampshire in production characteristics and has to some degree the desirable body conformation of the Dark Cornish.

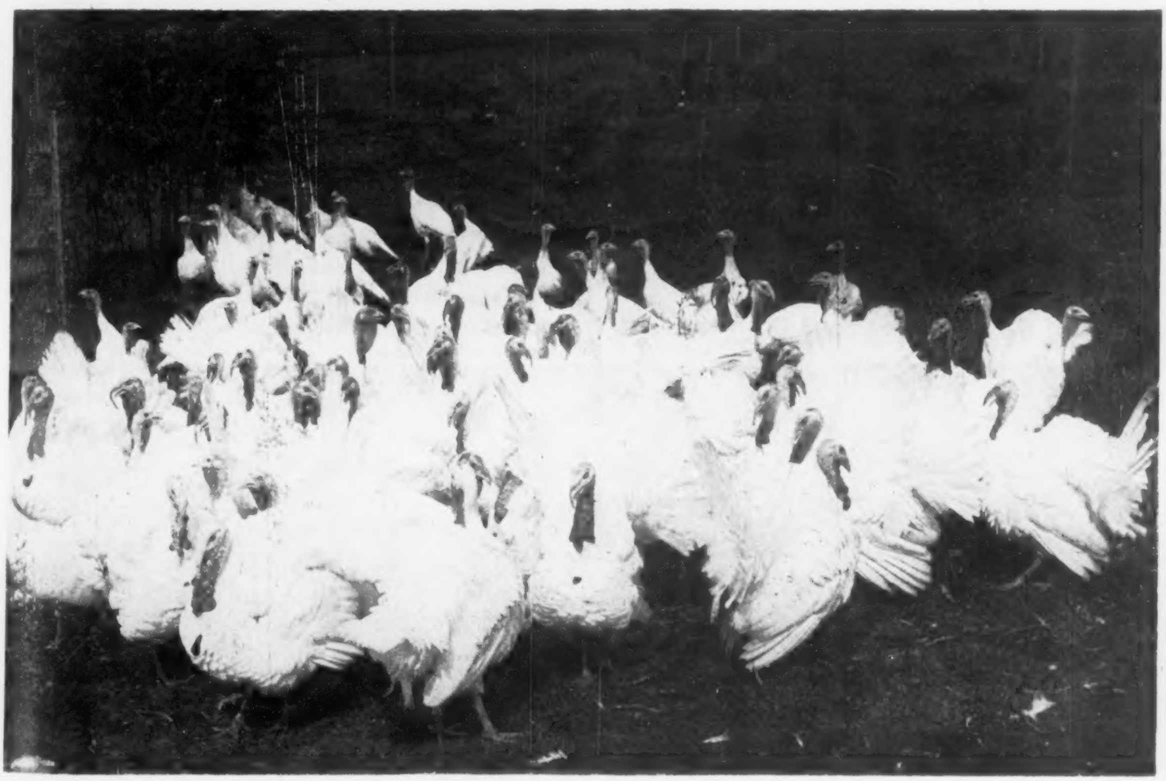
A redesigning job on turkeys preceded the present effort on meat-type chickens, and probably more people have heard of Beltsville through the Beltsville Small White turkey than through any other development. In 1934 the first matings were made with a view to producing a new breed of turkey that would be better adapted to apartment house ovens and small-family menus than were the large turkeys then available. Bronze, Black, Wild, White Holland, Narragansett, and White Austrian turkeys were used in the original crosses. Then by progeny testing and family selection there was developed a breed of small white turkeys characterized by high rate of egg production, fertility, and hatchability. Later there was some crossing with Broad-Breasted Bronze to improve body conformation. Acceptance of the new breed has been such that it is estimated that 20 per cent of all the turkeys grown in the United States in 1951 were Beltsville Small Whites. One unforeseen result has been that many turkeys have jumped from the oven into the frying pan. The lower cost of producing Beltsville White turkey poults and the high market quality of the 14- to 16-week-old birds of this breed have made turkey fryer production economical and have added a new enterprise to the poultry industry.

The nutritional requirements of the growing chicken have been catalogued more thoroughly than those of any other animal. They include protein, energy, 13 vitamins, 9 mineral elements, and 13 amino acids. The exploration of this field has extended over approximately the past 30 years, and it is not yet completed. It has occupied many research workers in many laboratories. It has changed poultry feed mixing from the strong-back-and-shovel method to a specialized industry requiring highly technical training. It has taken so much of the empiricism out of feed formulation that the quantities of all the above-mentioned nutrients sup-

plied by a tentative formula can be calculated and compared to the requirements. If the quantities of any of the nutrients fall short, it is not necessary to juggle the formula. It may be cheaper to add the necessary nutrients in synthetic form. Synthetic vitamin A, riboflavin, nicotinic and pantothenic acid, choline, and methionine are used in commercial poultry feeds. The industry also uses large quantities of vitamins B_{12} and D in the form of special supplements. As a result of the availability of these new sources, vitamins no longer are a major factor contributing to feed cost. Protein and energy components are major cost factors now and will be so for some time to come.

Difference in cost between different protein supplements helped materially to motivate the search for one unknown vitamin that is now known as vitamin B_{12}. Soybean meal production in the United States increased from 40,000 tons in 1929 to 4,582,000 tons in 1949. During most of this time soybean meal was a much more economical protein source than the animal protein supplements. It was soon learned, however, that soybean meal could not be freely substituted for animal protein supplements. It was first demonstrated at Beltsville in 1937 that supplementation with all the then known nutrients, including riboflavin, did not make a soybean meal–grain diet adequate for reproduction, but that some unknown factor was required. At first it was known to occur only in animal tissues, but later this mysterious "animal protein factor" required for both growth and reproduction was found at Beltsville in different source materials—namely, cow manure and chicken manure. The fact that it occurred in chicken manure even when absent from the chicken's diet strongly suggested microbial synthesis. Direct evidence for microbial synthesis was soon forthcoming from other laboratories, and commercial production of supplements containing the unknown factor was accomplished. Vitamin B_{12} was then isolated from liver in the laboratories of Merck & Co. as a bacterial growth factor and antipernicious anemia vitamin and was shown to stimulate growth of chicks fed all-vegetable rations. At Beltsville, the crystalline vitamin was shown to stimulate growth as effectively as a concentrate prepared from cow manure and, when injected into eggs deficient in the unknown factor, to improve hatchability and viability, growth, and feathering of chicks hatched.

It was found that feeding high levels of soybean meal increased the requirements for the unknown



A flock of Beltsville Small White turkeys.

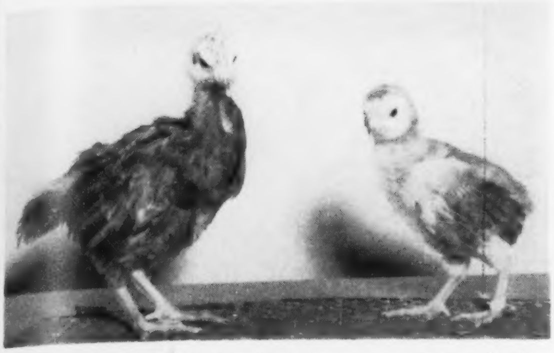
Result of feeding vitamin B_{12}-deficient diet to breeding hens. Of 100 fertile eggs set, 34 failed to hatch, and 19 produced chicks that died in the first week after hatching.

factor, and a chick assay method was based on this fact and on the use of chicks from depleted hens. This method is being used to assay feedstuffs for vitamin B_{12}. Many interesting discrepancies still exist between the results of chick assays and microbiological assays for this vitamin, indicating the need for additional study. Only a fraction of the B_{12} of eggs and tissues of chickens is recovered by the usual methods of extraction used in microbiological assays. Much higher values can be obtained by extracting with a very dilute solution of sodium cyanide. If B_{12} is added to egg yolk, it is in part bound so that it cannot be recovered by microbiological assay unless the samples are extracted with cyanide.

Vitamin B_{12} requirement is increased not only by a high level of dietary soybean meal but also by a high level of dietary glycine. This was first shown at the University of Maryland; a high glycine diet increased B_{12} requirement, and B_{12} overcame to a considerable extent the effects of glycine toxicity. These results were confirmed at Beltsville, and a surprising new observation was made. Vitamin B_{12} was effective in alleviating the unfavorable effects of high levels of glycine on growth and mortality, but instead of restoring to normal the high blood uric acid levels brought about by the glycine, B_{12} administration increased the blood uric acid still farther. Increasing the dietary level of folic acid reduced blood uric acid levels.

The most extensively used vitamin B_{12} supplements of microbiological origin are by-products of the manufacture of antibiotics. When these were first used, some produced a growth stimulus greater than could be ascribed to B_{12} alone, and this extra effect was identified in the Lederle Laboratories as a growth-stimulating effect of residual antibiotic. Subsequent experiments at Beltsville have shown that a suitable antibiotic stimulates growth when added to a diet that is complete in all known nu-

Result of supplementing same diet with fish meal to supply B_{12}. Of 100 fertile eggs set, 15 failed to hatch and 4 produced chicks that died in the first week of life.



Five-week-old chicks hatched from eggs of vitamin B_{12}-deficient hens. Chick on the left hatched from an egg into which was injected 0.5 μg of vitamin B_{12}. The other chick hatched from an uninjected egg.

trients. In the case of breeding stock, adding an antibiotic to a complete diet has no effect, but adding it to a diet deficient in vitamin B_{12} increases hatchability. Various theories have been suggested to account for the favorable effects of antibiotics on growth. Recent experiments conducted in England and confirmed at Beltsville showed that the effect could be explained, at least in large part, by the ability of the antibiotic to limit the growth of intestinal microorganisms that are detrimental to the host. Chicks kept in isolation in new quarters grew as rapidly without antibiotic as did chicks fed an antibiotic in old quarters.

Diets composed largely of grains and vegetable protein supplements other than soybean meal are improved by addition of B_{12} and antibiotics, but other factors are involved too. Work at the Southwest Poultry Experiment Station at Glendale, Arizona, has shown that, when growing chickens are fed a diet consisting largely of grains and cottonseed meal, growth is limited by the inadequate level of available lysine. By avoiding excessive heat in the processing of cottonseed meal, one achieves maximum availability of the lysine, but, even so, such a diet is improved by the addition of lysine. If such a diet is fed to laying hens, lysine is not a limiting factor, but gossypol, a toxic pigment of cottonseed, depresses hatchability and causes abnormal yolk color in the eggs produced. Gossypol is toxic to growing chickens as well as to embryos. Ordinary commercial processing reduces free gossypol content to a level that is safe for growing chickens but not to a level that is safe for laying hens.

The general belief that chickens require a diet having a high level of concentrates and low level of roughage can now be challenged on the basis of recent experiments. A diet containing 64 per cent of ground oat hulls, and a diet containing 25 per cent of ground hay, after being compacted by pelleting, have been fed successfully to laying hens.

Another generally accepted "truth" was recently proved false with the aid of a labeled, radioactive element. Chickens, as well as other animals, were supposed to be incapable of synthesizing the sulfur-containing amino acids, methionine and cystine, except that cystine could be formed from methionine. However, when dilute sulfuric acid containing radioactive sulfur was injected into laying hens, cystine containing radioactive sulfur was found in the proteins of their eggs. There was no radioactive sulfur in the methionine. Apparently, inorganic sulfur was used in the synthesis of cystine. Whether this synthesis is of any practical significance remains to be determined.

Since egg production is the major enterprise of the poultry industry, it is obvious that the physiology of reproduction of poultry has important practical aspects. It is also obvious that the laying hen is of particular interest to the physiologist studying reproduction. What other animal goes through daily ovulatory cycles through the whole year, with just a few lapses?

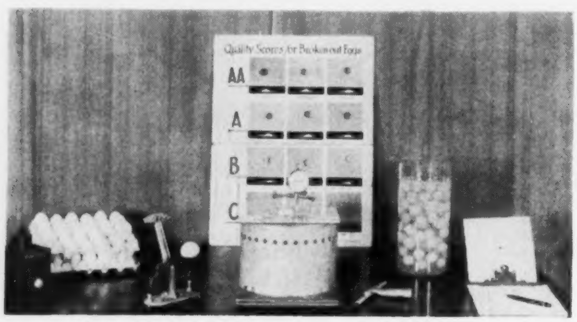
Studies at Beltsville directed toward the final goal of controlling egg production show that the release of the yolk from the ovary is brought about by a hormone liberated by the anterior pituitary four to six hours earlier. For the first egg in a sequence, the time of secretion of this hormone apparently depends on the lighting schedule or some associated factor. After release of the first egg of the sequence, the time of secretion of the hormone is altered by some factor associated with the preceding ovulation, and this relationship continues until the end of the sequence. There is experimental evidence that the hormone progesterone stimulates the pituitary to release the ovulation-inducing hormone, and progesterone may modify the effect of the environmental factor associated with the beginning of the cycle.

The six-week-old Rhode Island Red cockerel on the left received a diet complete in all known required nutrients and weighed 590 g. The other bird, of the same age, received the same diet plus 20 g aureomycin/ton of feed and weighed 765 g.

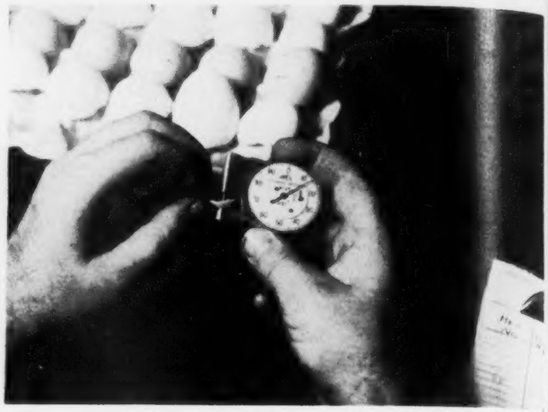
Prior to this series of studies progesterone was known to occur only in pregnant mammals. In these experiments it was shown to occur not only in the blood of hens but also in the blood of males. It seems likely that its function is more general than has been supposed.

Progesterone was found at higher levels in the blood of sexually active male turkeys than in the blood of inactive males. Sexual activity in male turkeys is of considerable practical importance, since it has been observed in commercial turkey flocks and also in the experimental flock that many male turkeys molt early in the spring and that during their molting period their semen production falls to levels insufficient to maintain fertility. This has been a serious problem in some flocks in recent years. The preseason molt is associated with an altered balance of the endocrine system brought about by the use of artificial lights. Many turkey males subjected to a 14-hour light day starting on December 1 begin to molt 8 to 10 weeks later. During the molt they lose weight, and semen production and fertility are considerably reduced at a time when hatching eggs are in greatest demand. Females in the same pens, subjected to the same environmental conditions, do not molt. Molt can be delayed in males by avoiding the use of artificial light. This is the best practical solution at present, although it involves keeping two flocks of males, one lighted for early fertility and one unlighted to supply replacements when the lighted males begin to molt. The preseason molt can also be prevented by adding 0.1–0.2 per cent of the antithyroidal drug thiouracil to the diet. This is not a practical solution since thiouracil itself at these levels reduces semen production and sexual activity.

Normally, fertilization of the hen's ovum occurs in the upper portion of the oviduct soon after ovulation. However, studies on fertilization have disclosed the curious fact that spermatozoa, at least in rare instances, are capable of penetrating an immature ovum on the ovary and later initiating development after maturation of the ovum. Semen was placed on the ovaries of chickens 4–17 weeks of age, and four fertile eggs were obtained as long as five months after application of the semen. In no case did development proceed very far.



Devices for measuring egg quality.



Measuring thickness of egg shell.

It has been known for some time that androgens, the class of substances responsible for secondary sexual characteristics of the male, stimulate increases in body weight of mammals of at least some species. An androgen, testosterone propionate, was found to increase weights of immature or mature but sexually inactive male turkeys. Furthermore, serum from pregnant mares was found to enhance the effectiveness of the androgen. During a 26-day experimental period, untreated young males and those receiving only the mares' serum increased in body weight by 20 per cent. The group receiving testosterone propionate alone increased in weight by 31 per cent, and the group receiving both mares' serum and testosterone propionate made a 38 per cent gain.

The quantity and quality of poultry products are influenced by the hereditary background of the poultry population and by the feeding and management of this population. "Quality" is an empirical composite of a variety of physical, chemical, and biological properties which provide many interesting subjects for study. The problem of determining quality of eggs without breaking the shells has been a perennial one. Studies have been made of the ability of egg components and intact eggs to transmit or reflect various forms of energy. Ultrasonic energy did not readily penetrate eggshell but is being studied further in the expectation that greater intensity may overcome the shell barrier. Radiofrequency energy was transmitted by eggs, but changes in quality of the egg components had little effect on transmission. As a result of studies

of the transmission of visible light of different wavelengths, a device has been developed which indicates the presence or absence of blood in white-shelled eggs with far greater accuracy than is attainable by present candling methods. The device is believed to be suitable for inclusion in a mechanical or automatic egg grader.

A very critical procedure has been devised to test fresh eggs for freedom from bacteria and to measure the rate of infection under unfavorable conditions. In this test the entire contents of an egg were mixed with other ingredients favorable to bacterial growth, and the mixture was kept at suitable temperature to permit any bacteria that might be in the egg to grow and thus reveal their presence. Even when subjected to this severe test, 88 per cent of fresh eggs proved sterile. Holding eggs at 59° or 77° F and 95 per cent relative humidity resulted in a considerable increase in percentage of infection within two weeks. When eggs were held at 41° F there was no significant increase in percentage of infection during this time.

The total results of research can never be weighed or measured or expressed in dollars and cents. In this case, however, it is possible to say, "Here are some measurable, quantitative advances that represent a part of the results of research on poultry in state, federal, and commercial laboratories." In 1945, three-pound chickens were produced in 12 weeks on 13.5 pounds of feed per chicken; in 1952, in 10 weeks on 8.25 pounds of feed per chicken. As a result of this change and a similar change in turkey production, chicken and turkey have changed from luxuries to staple foods. In 1941 average egg production per hen in the United States was 139; in 1951 it was 171. On the basis of these figures it can be calculated that in 1941, 7.4 pounds of feed were required to produce a dozen eggs; in 1951, 6.3 pounds.

The next time you eat a chicken, you might pause to reflect that its diet and the record of its family tree were probably more complete than your own.

All photos by U. S. Department of Agriculture.

SMO ON THE AIR

Station	Sponsor	Time
	Monday	
WOI-FM, **Ames, Iowa**	Iowa State College of Agriculture and Mechanic Arts (Articles of Interest)	7:45 P.M.
	Tuesday	
WEVD, **New York City**	Wendell W. Rázim (Science for the People)	9:00 P.M.
	Wednesday	
CKPC, **Brantford, Ont.**	The Telephone City Broadcast Limited (Modern Science)	9:45 P.M.
	(Irregular)	
KBER, **Baker, Ore.**	Baker-Union Department of Health (Research Report)	....

The Editor of The Scientific Monthly will be glad to cooperate with university or other educational stations interested in securing scientific material suitable for broadcasting.

SCIENCE ON THE MARCH

THE SCHUSS-YUCCA

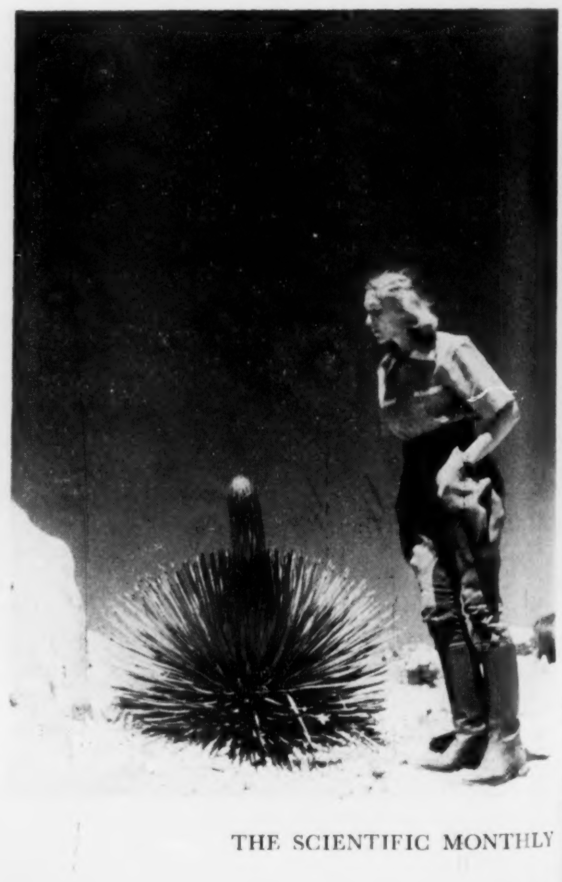
(*Yucca Whipplei,* var. *Schuss*)

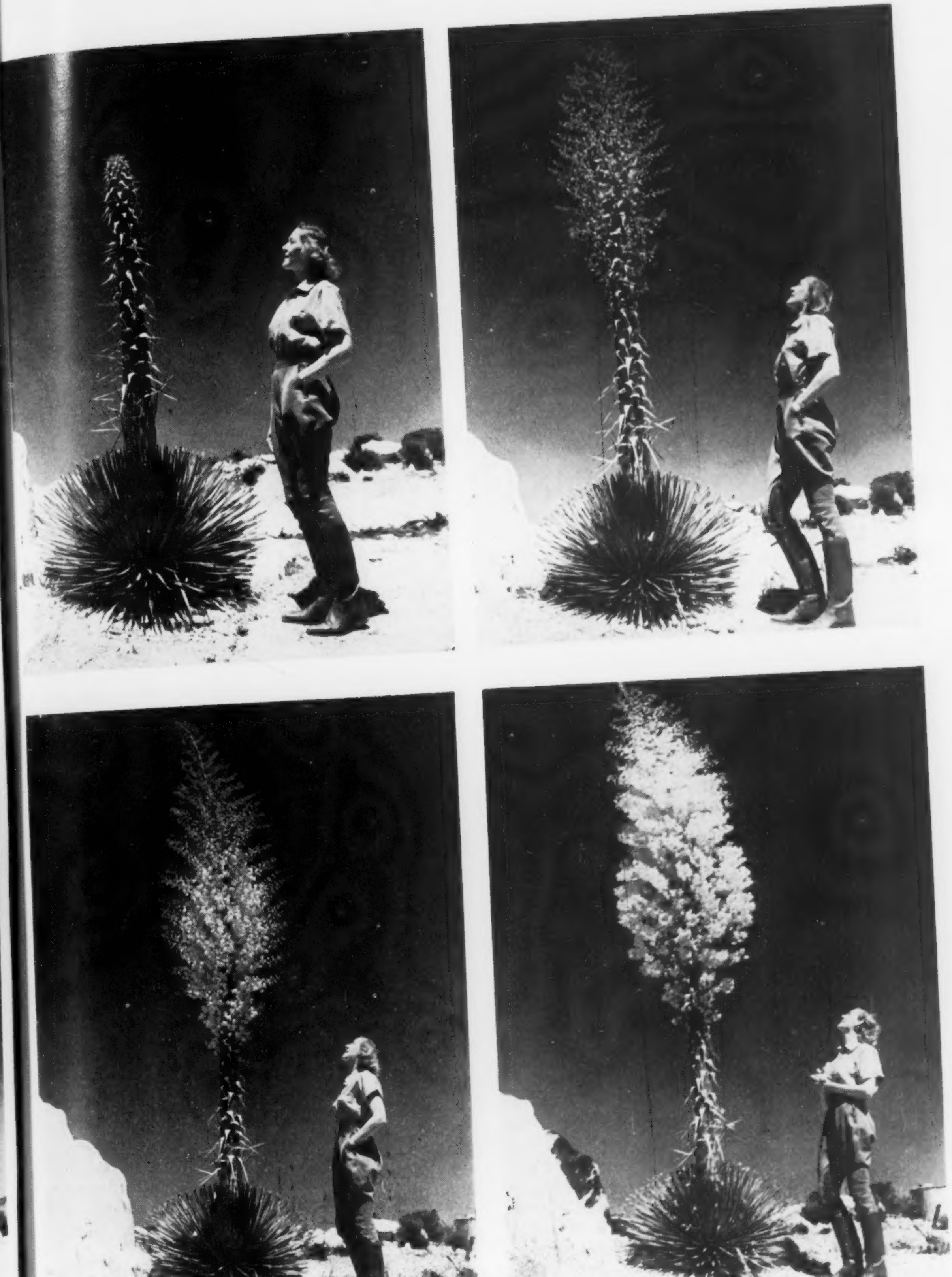
ONE of the most amazing, and still unexplained, phenomena in botany is the *Schuss-yucca,* a rare variety of the chaparral yucca (*Yucca Whipplei*), which occurs here and there about Chilao Flat in the San Gabriel Mountains north of Pasadena, a locale noted for its queer flora and fauna. The normal variety of Yucca Whipplei grows for many years as a hemisphere of sharp and awesome spines (Spanish bayonet); then some spring day a large shoot rises ten to twenty feet in a period of two or three weeks, blooms, and dies. The Schuss-yucca of Chilao Flat does this in a matter of minutes or even seconds! (See photographs.)

Although described in a brief note in Liebig's *Annalen* (1853), the first thorough investigation of this amazing plant was made by the eminent German botanist Professor Ferdinand Grünspann, who visited Chilao Flat, riding a burro, in the spring of 1890, and who devoted Volumes 13 and 14 of his exhaustive twenty-volume work, *Handbuch der Yucca* (Leipzig: Schmutzig-verlag [1893] —now out of print and hard to find), to a description of this remarkable variety of the chaparral yucca. In spite of Professor Grünspann's reputation and careful research, his observations on the Schuss-yucca, (a name he himself applied to it from the German *Schuss,* "to shoot up") were not credited by contemporary botanists, who considered it a hoax (*zum lachen*). Although most of the professor's work was undoubtedly accurate, he apparently let himself be taken in by certain tall stories of the Indians, one tale in particular doing much to discredit his whole study. Grünspann tells of the Spanish desperado and cattle rustler Vasquez being impaled in midair by a Schuss-yucca while he (Vasquez) was jumping over the plant. This story possesses undoubted charm, but it is probably a canard. The Schuss-yucca does shoot up with amazing rapidity in a matter of seconds, but the shoot is soft, like a giant asparagus, and is frequently eaten by deer (which can be seen waiting about near plants that they somehow know are ready to sprout); hence, it could not reasonably be expected to harm a full-grown Spaniard.

This story, and the lack of imagination common at that time, combined to discredit Professor Grünspann. It is said that the professor's dying words were *"Es schiesst doch!"*—reminiscent of Galileo's famous remark some centuries earlier, *"Eppur si muove!"* But rumors about the Schuss-yucca, which the natives picturesquely refer to as the "jumpin' Yuccy," have persisted about Chilao Flat. One rumor originated at Mount Wilson a few miles to the south from an astronomer who was fooling around with the 100-inch telescope between exposures of the planet Mercury, and another from a skier who had got off his course in a *slalom* race down Mount Waterman.

Since I had myself seen and photographed another queer yucca in this area last year—*Yucca Whipplei,* var. *bifurcata* (mihi)—(SCIENCE, 115,





219 [1952]), I determined to investigate the Schuss-yucca, and if possible bring back incontrovertible photographic evidence.

My model and I, laden with cameras and a fifth of antivenin (the rattlesnakes, too, are said to be unusually swift and accurate at Chilao Flat), haunted the region for days. We were guided by the deer, whose uncanny instinct tells them which yucca plants to watch, and we were finally rewarded for our perseverance, as the accompanying photographs show. I used an automatic Rolleiflex, taking the photographs at one-second intervals, and although the exposures were only 1/100 of a second, there is little blurring of the fast-moving sprout. The amazement on the face of the model, who was somewhat dubious of the whole affair, is clearly evident.

It is somewhat sad that cameras were not as well developed in Professor Grünspann's time—he might have died a happier man. It is also regrettable that scientists as a class were so skeptical then. Scientists today realize that anything is possible, whether Schuss-yuccas or extra-terrestrial flying saucers—particularly when reported by trained and reliable observers and accompanied by good photographs.

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BOOK REVIEWS

THE STRUGGLE FOR EXISTENCE

Parasitism and Symbiosis. Maurice Caullery; translated by Averil M. Lysaght. xii + 340 pp. Illus. $4.50. Sidgwick & Jackson, London; Macmillan, New York. 1952.

THIS volume, one of the publisher's series of textbooks of animal biology edited by H. Munroe Fox, deals with the broad biological facts and concepts of parasitism, commensalism, and symbiosis, and their subcategories, such as inquilinism and mutualism. As the author correctly points out, commensalism, parasitism, and symbiosis are not really discrete, discontinuous phenomena in nature, but are merely different aspects of one general theme. Their differences are more of degree than of kind, and their continued usage in biological writing is a man-made convenience. To some extent parasites are the organisms in which evolution is most obviously apparent. Not only are most of them highly adapted to peculiar and special conditions, but also they were evolved after the differentiation of the various groups of animals and plants that form their hosts. They are, to this degree, the results of a secondary evolution that is less remote than the major primary one.

The book deals with both animal and plant forms and cases but is preponderantly zoological. For various reasons the field of bacteriology (most bacteria would come under the heading of parasites) is merely mentioned but not discussed in detail. In the animal kingdom the author has cast his nets widely and drawn in a broad sampling of parasites, symbionts, and commensals. He admits to having attempted to get away from the old classical examples and to replace them by less well-known instances illustrative of the various stages of parasitism. This is commendable from the standpoint of the reader already versed in the field, but not necessarily so for the beginner who might use the book as a textbook. After all, the thing that has made certain cases "classical" is that they have been more completely studied, are more available for study, and present the situation clearly. The reviewer was surprised to find, for example, no mention of so famous a case of parasitic behavior as the breeding habits of parasitic birds, not even of the European cuckoo. But the many other instances described afford a good corpus of data and will be useful for this reason even to advanced students.

Among the topics discussed are commensalism, both in marine and terrestrial organisms; inquilinism; the general nature of the types of modification produced by parasitism (with numerous examples, chiefly in annelids, mollusks, and crustacea); temporary parasitism (entomophagous insects, Gordian worms, copepods, etc.); parasites that change their hosts (cestodes, nematodes, acanthocephala, protozoa, parasitic plants, etc.); the adaptive modifications shown in the reproductive pattern of parasites (increase of egg production, hermaphroditism, change of sex, etc.); the specificity shown in parasites and the modes of host infection (the degrees of specificity, host-parasite equilibrium, tropic prophylaxis, etc.); the reciprocal reactions of parasite and host (phagocytosis, parasites and toxins, parasitic castration, gall formation, etc.); symbiosis between animals and plants (ectosymbiosis such as found in ants and fungi, or termites and fungi; endosymbiosis as exemplified by protozoa and intestinal bacteria, termites and flagellates, blood-sucking animals, and animal luminescence); and symbiosis in plants (lichens, myxomycetes, mycorrhiza, etc.).

In a final philosophical discussion chapter the author concludes that all those phenomena and highly varied case histories are manifestations of the struggle for existence, characterized by specialization, but, ". . .

deprived of all finality or pre-established harmony. Those associations survived which balanced their accounts in a fashion compatible with the existence and perpetuation of the associates; many others must have arisen from time to time but have not lasted through failing to satisfy this necessity. . . ."

The book is illustrated by 80 text figures, has a good bibliography, and is well indexed.

Fleas, Flukes and Cuckoos. Miriam Rothschild and Theresa Clay. xiv + 304 pp. Illus. $8.75. Philosophical Library, New York (printed in Great Britain). 1952.

THIS volume, written by two of the world's most assiduous students of the ectoparasites of birds will be a welcome addition to the bookshelves of all students of bird lice and bird fleas, as well as students of the birds themselves. The specialist on flukes or parasitic birds will find less in it in his own field but should get some broadening glimpses of the related, although different, fields dealt with. The subtitle "A Study of Bird Parasites" explains why the authors felt it worth while to include such heterogeneous types of parasites as protozoa, fleas, and skuas. Skuas are more properly to be looked upon as predators than as parasites ("cleptoparasites," as the authors attempt to distinguish them), but one may allow the authors their excursion into related fields, although wondering where such meandering might lead them, and what criteria would limit them.

The ornithologist will, however, benefit from the clearly expressed description of the multitude of parasitic denizens on the inside and outside of birds, with all their variety of forms and habits, a swarm of such complexity as to have caused A. E. Shipley to describe the hosts as "not only birds, but aviating zoological gardens." The different degrees of parasitic relationships found in this bird-borne fauna have necessitated some attempt to make the reader aware of the various stages of the theme by discussions of parasitism, commensalism, and symbiosis. These chapters are followed by others dealing with the effects of parasites on the host, the effects of parasitic living on the parasites themselves, and a résumé of what may be deduced concerning the origin of parasitism and the evolution of parasites. This last, by the way, seems to the reviewer to carry less conviction than other sections of the book. To a large extent this may, of course, be due to the absence of sufficient data at present. These preliminary chapters take up a little over 50 pages of the book. The next part, with twice as many pages, deals with bird fleas and bird lice and is, in the opinion of this reviewer, the most valuable part of the book. The third section, of about 100 pages, treats of protozoa, worms, flies, mites, tongue-worms, microparasites, such as bacteria, and of the complicated fauna inhabiting birds' nests.

One cannot help but wonder if it may not have been this attempt to describe the parasitic fauna of birds' nests that is responsible for the chapter devoted to the European cuckoo (here taken as a type for all the brood parasites among birds). A chapter on food-robbers, for which the skua is used as an example, seems a little far-fetched; the book would have suffered no loss by its omission, as it adds nothing very germane to the main topic. All in all, however, the authors have produced an interesting and valuable survey of the heterogeneous fauna termed the parasites of birds.

A useful bibliographical appendix, necessarily short, an index to the popular and scientific names of organisms mentioned in the text (including a separate one of bird names), and a general index complete the volume.

HERBERT FRIEDMANN

Division of Birds
U. S. National Museum

BRIEFLY REVIEWED

A Field Guide to the Mammals. W. H. Burt and R. P. Grossenheider. xxi + 200 pp. Illus. $3.75. Houghton Mifflin, Boston. 1952.

WILLIAM HENRY BURT, a distinguished teacher, and curator of mammals at the University of Michigan, and Richard Philip Grossenheider, a skillful artist, have collaborated in a superb field guide to the 373 species of mammals known in America north of the Mexican boundary. Using the ingenious Peterson system of identification, each species is viewed from different angles: a short diagnostic description, a map showing its distribution, and an illustration either in color or in black and white, with the distinguishing specific character indicated by a line. One hundred and eighty-seven species are beautifully illustrated in full color. The treatment is very simple and can quite easily be used by any layman in identifying a species.

If the collector does not find the animal itself but only its skull, there are dental formulas and a series of photographs that will help him to identify it; or if he finds nothing but the tracks, there is a splendid series of pictures of footprints.

The entire book is a most valuable contribution to the study of North American mammals. It is sponsored by the National Audubon Society and the National Wildlife Federation.

W. M. MANN

National Zoological Park

Flour for Man's Bread. John Storck and Walter Dorwin Teague. vi + 382 pp. Illus. $7.50. University of Minnesota Press, Minneapolis. 1952.

"WE HAVE come a long way from the dawn man who gathered the seeds of wild grasses and crunched them between his molars or ground them between two stones," according to this comprehensive history of milling. "The ways in which man has made flour for his bread have forged the patterns of technological progress: the refinement of tools, the increasing use of power, the development of large scale production and distribution."

The story is told by the industrial designer Walter

Dorwin Teague in collaboration with John Storck, author of *Man and Civilization.* It is illustrated by hundreds of graphic drawings; has a complete index and vocabulary; is enlarged by an extensive, but not complete, bibliography. The project was planned first as a "museum of milling history;" when it was abandoned, its wealth of material became this tremendous book.

As many as 75,000 years ago, say the archaeologists, man began the basic processes of milling as we know them today: "the breaking up of cereal grain seeds and the removal from the resulting meal of the unwanted portions." The book pictures the earliest methods and the ensuing improvements through the years. Civilization itself has been an outgrowth of tilling the soil, of growing, grinding, sifting, cleaning, and purifying grain.

The great grain empires of Egypt and Mesopotamia had time to develop little else. "We do not know when leavening was first used . . . but the Romans were the first to make bread comparable to our own." The use of water power provided an impetus to a movement "which would culminate in the Industrial Revolution." Water wheels, windmills, millstones, querns, rollers: circumstances suggested the means. "In this progress we can see the expansion of the scope of reason, until it came to guide men's everyday acts as well as their speculative thinking." Throughout history "the expansion of grain lands has been life-giving in a realistic sense."

From the days of grain growing in the regions of the Tigris, Euphrates, and Nile, that theme is developed and extended to show its effects through Europe and into America. Here, new grains and new methods were found. Canals and railroads helped distribute the product. Oliver Evans invented an automatic mill and lived to see it run by steam engines. Today the basic processes continually undergo constant improvement.

It is an overly large book and (perhaps necessarily) somewhat redundant. Yet, if you can bear its weight in your hands, you will find in it philosophy, anthropology, geology, sociology, and the related sciences, as well as a detailed account of milling methods.

MARJORIE B. SNYDER
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Statistical Theory with Engineering Applications. A. Hald. xii + 783 pp. Illus. $9.00. Wiley, New York; Chapman & Hall, London. 1952.

THE present book is an introductory text in statistics for engineers and requires familiarity with the calculus. It begins with an introduction to probability and then covers the topics now standard for a statistics text. The illustrative examples are largely drawn from engineering practice, and there are also chapters on the distribution of the range and on statistical control. In his preface the author states that he has followed the ideas of Fisher and Shewhart. His debt to the former is, however, not so great as to preclude him from treating the problem of interval estimation by means of confidence intervals, and from discussing the notion of power of a test. Unfortunately, like almost every other text, the author never says what a test of significance really is (i.e., a method of decision between two alternatives), but merely describes how to perform tests of significance.

Naturally the reviewer differs with the author as to how certain topics should be treated. For example, it seems incorrect to have chapters on graphical and tabular representation of observations and on the properties of empirical distributions precede any discussion of distribution functions, or, for the matter of that, much discussion of probability at all. It is important to present in the proper light the relation of probability theory to the problems of estimation from empirical data. As another example, the chapter on sequential analysis is all too brief. In it the author states that he will consider only the Wald sequential probability ratio test. He could easily have stated why: (1) there is no other systematic theory of sequential tests, (2) the Wald test is optimal in a certain precise sense.

This is a competent and conscientious first book on statistics. The author has tried particularly to include new results in the classical direction which may be useful in engineering applications. The format is excellent.

J. WOLFOWITZ
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Musical Engineering. Harry F. Olson. 357 pp. Illus. $6.50. McGraw-Hill, New York. 1952.

WRITTEN by an acoustical engineer for engineering students and members of his profession, this is also a book that should appeal to the educated layman who is interested in music and in modern problems of its recording and reproduction.

Detailed and well-illustrated discussions of musical terminology and notation, the scales, and musical instruments of all kinds follow an introductory chapter on sound waves. The tonal and dynamic properties of musical instruments are described in detail, with graphs of the frequency spectra and diagrams of directional characteristics given for many of them.

In the chapter on the properties of music, the physical structure of the hearing mechanism is well described, and the "psychological characteristics"—pitch, loudness, timbre, etc.—are defined and discussed.

The final chapters are devoted to the acoustical problems of theaters, studios, and other enclosures in which sound-reproduction, sound-collecting, and sound-reinforcing problems are encountered. Sound-reproducing systems for many applications, including the hearing aid, are described and illustrated.

The book is most generously supplied with excellent illustrations and written in a clear and readable manner. Literature references appear as footnotes.

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ASSOCIATION AFFAIRS

REVISION OF THE AAAS CONSTITUTION AND BYLAWS

WHEN the Association met at St. Louis in 1946, one of the important actions taken was the adoption of a new constitution (SCIENCE, 103, 245 [1946]). It was recognized that the Association's bylaws should have been revised simultaneously so as to conform with the new constitution, but it was not until 1950 that any serious attempt was made to harmonize bylaws and constitution. At that time a committee comprising Kirtley F. Mather, *Chairman*, Clarence E. Davies, Karl Lark-Horovitz, Roger Adams, and Howard A. Meyerhoff, *Secretary*, turned to the task but soon concluded that the 1946 constitution required amendment or replacement. In many particulars it was so specific as to ursup the function of bylaws and, in prescribing certain administrative procedures, it was not only at variance with current practice but precluded the flexibility that is essential to the efficient conduct of business in an organization as large as the AAAS.

At Cleveland, on December 29, 1950, the Council authorized the committee to revise the constitution, in addition to preparing a new set of bylaws. The Council also approved in principle the basic changes that are embodied in the following document, in which constitutional articles and related bylaw provisions are printed consecutively. This document is merely a semifinal draft of a new constitution and bylaws, the final drafts of which, it is hoped, will be placed before the Council for action at meetings in St. Louis, December 27 and 30, 1952. Conferences with the Association's legal and financial advisers have indicated the need for some revision in Article II, Section 3, of the bylaws; in Article V, Section 2, of the bylaws; in Article XI, Section 1, of the constitution, and several sections in the corresponding article of the bylaws. Other modifications may be prompted by suggestions received from members, who are herewith invited to comment and to send any suggestions to the chairman of the committee or to the Administrative Secretary without delay.

In conformance with Article XI of the constitution now in force, the final drafts of the proposed constitution and bylaws will be published in SCIENCE and in THE SCIENTIFIC MONTHLY in November, at least one month prior to the annual meeting of the Association, and the Council will be asked to act upon the final drafts at one of its sessions, either on December 27 or December 30.

The most significant change contained in the proposed constitution is in the allocation of responsibilities. At present it is stipulated that "control of all affairs of the Association is vested in the Council, which shall have the power to review and to amend or rescind its own actions and all actions taken by the Executive Committee." It is obvious that the Council is not in a position to assume such responsibilities but must delegate them to carefully selected representatives of its own choosing; hence, in the new constitution it is proposed to give the Council the responsibility of electing the members of the Board of Directors (which will replace the present Executive Committee), and to this Board will be delegated the duty of managing the business affairs of the AAAS. Inasmuch as the members of the Board will be individually and collectively responsible to the Council, which also retains the power to determine and to define policies, the Council remains the governing and the controlling body, as it should; it merely relinquishes a role it cannot satisfactorily fill—namely, that of being an administrative body.

It is hoped that the members of the Association, as well as of the Council, will endorse this proposal, which will enable the administrative staff, under the direction of the Board of Directors, to carry on the ramified business functions more efficiently and with fewer legal involvements than can be achieved under the 1946 constitution. The draft of the proposed constitution and bylaws follows.

Constitution—*Article I*

Section 1. The American Association for the Advancement of Science was incorporated by an act of the General Court of the Commonwealth of Massachusetts in 1874. The Association is a nonprofit scientific and educational body.

Section 2. The objects of the American Association for the Advancement of Science are to further the work of scientists, to facilitate cooperation among them, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation to the importance and promise of the methods of science in human progress.

Bylaws—*Article I*

Section 1. The objects of the Association shall be accomplished by conducting meetings and conferences of those interested in various branches of science and education, producing and distributing publications, administering gifts and bequests as prescribed by the donors thereof, supporting research, making awards to recognize accomplishments in science, cooperating with other organizations in the advancement of science, and engaging in such other activities as shall have been authorized by the Board of Directors.

Constitution—*Article II*

Section 1. The membership of the Association shall consist of Members, Fellows, and Associates. Individuals in any of these three groups may become life members, emeritus members, and sustaining members in accordance with the provisions of Section 5 of this Article and with such relevant rules as the Board of Directors shall have prescribed.

Section 2. Members. Any person, institution, or organization may be admitted to the grade of Member. Each Member shall have such rights and privileges and shall

pay such annual dues as the Board of Directors shall have prescribed.

Section 3. Fellows. Any person who shall have made a meritorious contribution to science may become a Fellow of the Association under such procedures as the Board of Directors shall have prescribed.

Section 4. Associates. Any person who shall have a record of leadership in any field related to science and who wishes to cooperate in the advancement of science may become an Associate of the Association under such procedures as the Board of Directors shall have prescribed.

Section 5. (*a*) *Life Members.* Any person making the Association a life-membership contribution of such amount as the Board of Directors shall have prescribed may be admitted to life membership. Each Life Member shall be exempt from the payment of annual dues and shall have all the privileges of an annual member throughout life.

(*b*) *Emeritus Members.* Any individual annual member may be admitted to emeritus membership under such conditions as the Board of Directors shall have prescribed. Each Emeritus Member shall be exempt from the payment of annual dues and shall have all the privileges of an annual member throughout life.

(*c*) *Sustaining Members.* Any person making to the Trust Funds of the Association a sustaining membership contribution of such amount as the Board of Directors shall have prescribed shall be the founder of a Sustaining Membership, which shall bear his name and shall be maintained in perpetuity as a trust. Each incumbent of a sustaining membership shall have all the privileges of a life member. The first incumbent of a sustaining membership may be either the founder himself or another person named by him, as he may choose. On the death or resignation of an incumbent, the Board of Directors shall name another person to hold the membership throughout life.

Bylaws—*Article II*

Section 1. Members who have paid dues for fifty years may be excused from further payments and still retain all the privileges of membership.

Section 2. Members may be elected by the Board of Directors to be Fellows of the Association and Fellows so elected shall remain Fellows only so long as they retain membership. If a Fellow discontinues his membership and subsequently rejoins the Association, he shall automatically again become a Fellow from the time of rejoining, without another election. Members are eligible to nomination for fellowship if they have contributed to the advancement of science either by the publication of original research or in other significant manner. Nominations for election to fellowship may be made by any three Fellows or by the administrative secretary or by the section committee in whose field the nominee's scientific work mainly lies.

Section 3. The Board of Directors may exclude from the Association anyone who has made improper use of his membership or whose membership is regarded as detrimental to the Association.

Constitution—*Article III*

Section 1. The officers of the Association shall be (*a*) general officers elected from among the Fellows by ballot of the Council, and (*b*) administrative officers elected by the Board of Directors as prescribed in Section 3 of this Article.

Section 2. General Officers. The general officers of the Association shall be a president-elect, a president, a retiring president, and a vice president for each section. The term of office of the president-elect and of the vice presidents shall begin on the January 15 following their election. At the close of the one-year term of the president-elect he shall become president, and at the close of the one-year term of the president he shall become retiring president. In the event of a vacancy in the office of the president, the president-elect shall become president. In the event of a vacancy in the office of president-elect, the Board of Directors shall make a pro tempore appointment to hold until the vacancy shall have been filled by ballot of the Council. In the event of a vacancy in the office of vice president the Board of Directors shall fill the vacancy by appointment.

Section 3. Administrative Officers. The administrative officers shall be an administrative secretary, one or more associate or assistant secretaries, a treasurer, and, in addition, a secretary for each section. The administrative secretary, the associate or assistant secretaries, and the treasurer shall be elected by the Board of Directors. The secretaries of the sections shall be nominated from among the Fellows by the respective section committees and elected by the Board of Directors. The terms of office of each administrative officer shall be determined by the Board of Directors. The Board of Directors shall fill vacancies in the administrative offices.

Section 4. The duties of the officers shall be customary to those of the office and as further defined in the bylaws.

Bylaws—*Article III*

Section 1. The administrative secretary shall serve as secretary to the Council and to the Board of Directors; he shall be in charge of the Association's offices and shall manage the affairs of the Association in accord with procedures determined by the Board of Directors. He shall be an ex officio member of all standing committees.

Section 2. The treasurer shall perform the usual duties and those assigned in the bylaws.

Section 3. Reports of the administrative secretary and the treasurer shall be made in the manner prescribed by the Board of Directors.

Constitution—*Article IV*

Section 1. The Council shall perform duties prescribed in the constitution and shall act as an advisory body in matters pertaining to the general policies of the Association.

Section 2. The Council shall consist of (*a*) the president-elect, the president, retiring president, the vice presidents, secretaries of the sections, the administrative secretary, the treasurer, and the eight (8) elected members of the Board of Directors; (*b*) one Fellow elected by each regional division of the Association; and (*c*) the representatives of affiliated organizations as provided in Article VIII of this constitution. Each Council member shall serve until his successor shall have taken office. The president shall be chairman of the Council; if the president shall be unable to serve as chairman at any session, the Council members in attendance shall elect a chairman for that session. Twenty (20) members of the Council shall constitute a quorum for the transaction of business.

Section 3. The Council shall meet during the annual meeting of the Association and at other times on the call of the president or upon the written request of twenty (20) members of the Council.

Bylaws—*Article IV*

None.

Constitution—*Article V*

Section 1. The Board of Directors is the legal representative of the Association and as such shall have, hold, and administer all the property, funds, and affairs of the Association.

Section 2. The Board of Directors shall consist of eleven (11) members, the president-elect, the president, the retiring president, and eight (8) Fellows elected by the Council, two each year, for a term of four years. At any election of members of the Board of Directors not more than one Fellow serving his fourth consecutive year as an elected member may be re-elected. In the event of a vacancy in the office of an elected member of the Board of Directors, his successor for the remainder of the year shall be elected from among the Fellows by the Board of Directors and, for the remainder of the unexpired term, his successor shall be elected by the Council at the next annual election. Five (5) members of the Board of Directors shall constitute a quorum for the transaction of business. The retiring president of the Association shall be chairman of the Board of Directors. If he shall be unable to serve at any session of the Board, the Board members in attendance shall elect a chairman for that session. The administrative secretary and treasurer shall be ex officio members of the Board of Directors without vote.

Section 3. The Board of Directors shall hold four (4) meetings a year, one of which will be at the annual meeting. The Board of Directors shall also meet at the call of the chairman.

Section 4. The Board of Directors shall appoint such committees as may be necessary to aid in the management of the Association. The duties of standing committees shall be stated in the bylaws.

Section 5. The term of office of each of the eight (8) regularly elected members of the Board of Directors shall begin on January 15 following his election, and each shall serve until his successor shall have taken office.

Bylaws—*Article V*

Section 1. The committees shall be standing as provided in the bylaws or special as the Board of Directors approves.

Section 2. The Investment Committee shall advise the Board of Directors regarding purchase and sale of securities for the Association and shall make recommendations to the Board of Directors on financial questions. The Investment Committee shall consist of five (5) members appointed by the Board of Directors and selected from outside the Board of Directors, and the treasurer and administrative secretary. Each appointed member shall serve a term of five years, the term of one member expiring on January 15 of each year. Each shall serve until his successor shall have taken office.

Section 3. The Committee on Affiliation and Association shall review applications for affiliation or association with the Association and make recommendations thereon to the Board of Directors. The committee shall consist of five (5) members appointed by the Board of Directors. Each member shall serve a term of five (5) years, the term of one member to expire on January 15 of each year. Each shall serve until his successor shall have taken office.

Section 4. The Publications Committee shall give continuing scrutiny to the publications of the Association, the policies pertaining thereto, and make recommendations thereon to the Board of Directors. The committee shall consist of five (5) men appointed by the Board of Directors. Each member shall serve a term of five (5) years, the term of one member to expire on January 15 of each year. Each shall serve until his successor shall have taken office.

Constitution—*Article VI*

Section 1. The Association shall be organized in sections in accordance with the fields of interest of its members, as determined by the Council. Each member of the Association may designate the section in which he wishes to be enrolled and may designate an additional section in which he is interested.

Section 2. The vice president for a section shall be ex officio chairman of that section.

Section 3. The affairs of each section shall be managed by a section committee consisting of (*a*) the chairman and the secretary of the section; (*b*) other members of the Council who are primarily enrolled in the section; and (*c*) four (4) Fellows, one elected each year by the section committee for a term of four (4) years. No person shall serve concurrently on more than one section committee. If an elected member of a section committee shall have resigned or died, his successor for the remainder of the unexpired term shall be elected from among the Fellows by the Board of Directors, from nominations made by the section committee. One third of the members of a section committee shall constitute a quorum for the transaction of business.

Section 4. The section committee of each section shall promote the work of the Association in its own field and may organize subcommittees for that purpose. It shall arrange such section programs as it shall deem desirable for meetings of the Association, either separately or in cooperation with other sections of the Association or with independent societies. With the approval of the Board of Directors a section committee may arrange section meetings to be held at places and times other than those of Association meetings.

Bylaws—*Article VI*

Section 1. Council representatives of affiliated organizations which are not specifically related to an established section of the Association may be assigned to section committees in accordance with their requests.

Constitution—*Article VII*

Section 1. Regional divisions and local branches of the Association may be authorized by vote of the Council, for the purpose of promoting the work of the Association in their respective territories.

Section 2. Each regional division or local branch shall elect its officers for such terms as it shall prescribe and shall hold its meetings and conduct its affairs as it shall deem desirable, subject to the relevant provisions of this constitution and of the bylaws of the Association, and to such special provisions as the Board of Directors of the Association shall have established.

Bylaws—*Article VII*

Section 1. Regional divisions authorized by the Council have full control of their meetings, of their affiliations with other scientific organizations, and of all activities to promote the advancement of science in their territory.

Section 2. The Pacific Division (organized in 1915) in-

cludes members of the Association resident in British Columbia, Washington, Oregon, California, Idaho, Nevada, Utah, and the Hawaiian Islands.

Section 3. The Southwestern Division (organized in 1920) includes members of the Association resident in Arizona, New Mexico, Colorado, Sonora, Chihuahua, and Texas west of the 100th meridian.

Section 4. The Alaska Division (organized in 1951) includes members of the Association resident in Alaska.

Section 5. Each division shall receive for its expenses an annual allowance not to exceed one dollar for each of its members in good standing.

Constitution—*Article VIII*

Section 1. To facilitate cooperation between the Association and other organizations, and among the latter, the Council may, on recommendation of the Board of Directors, elect an organization to be an official affiliate.

Section 2. Each organization thus designated an affiliate shall be entitled to name one Fellow of the Association to represent it in the Council; if it has more than 100 members who are Fellows of the Association, it shall be entitled to name an additional Fellow to represent it on the Council.

Section 3. On recommendation of the Board of Directors, the Council may elect an organization to be an official associate. Associated organizations shall have the same rights and privileges as affiliated organizations except for representation on the Council.

Bylaws—*Article VIII*

Section 1. The names of affiliated and associated organizations shall be published from time to time as directed by the Board of Directors.

Section 2. Affiliated academies of science shall receive for research an annual allowance of fifty cents for each of their members who is also a member in good standing of the Association.

Constitution—*Article IX*

Section 1. The Association shall hold an annual meeting each year at such time and place as the Board of Directors shall have determined. Other meetings of the Association or of its sections may be authorized by the Board of Directors.

Bylaws—*Article IX*

Section 1. The programs and arrangements for the Association meetings shall be under the general direction of the Board of Directors.

Constitution—*Article X*

Section 1. The publications of the Association shall be issued in such manner as the Board of Directors may direct.

Bylaws—*Article X*

Section 1. The publications of the Association shall be (*a*) SCIENCE, (*b*) THE SCIENTIFIC MONTHLY, (*c*) *Proceedings*, and (*d*) such other special publications as the Board of Directors may direct.

Section 2. The Association shall not be responsible for statements or opinions advanced in papers or in discussions at meetings of the Association or its sections, divisions, or branches, or printed in its publications.

Section 3. The Association reserves the right to copyright, at the discretion of the Board of Directors, any of its papers, discussions, reports, or publications.

Constitution—*Article XI*

Section 1. The deposit, investment, and disbursement of all funds shall be subject to the direction of the Board of Directors.

Bylaws—*Article XI*

Section 1. All funds shall be paid into the business office of the administrative secretary, where they shall be entered in the books of the Association, and deposited to the account of the treasurer in a bank designated by the Board of Directors.

Section 2. All bills against members and others shall be made and collected by the business office of the administrative secretary.

Section 3. All expenditures shall be made in accordance with the budget of appropriations as adopted by the Board of Directors.

Section 4. All payments shall be made upon competent certification as to correctness and proper authorization by the business office from a Business Office Account kept in a bank designated by the Board of Directors.

Section 5. The treasurer shall reimburse the Business Office Account for payments made therefrom upon orders signed by the administrative secretary of the Association; or in the absence or temporary incapacity of the administrative secretary by an associate or assistant administrative secretary of the Association.

Section 6. Checks against the accounts of the Association will bear two signatures, from a list of individuals determined by the Board of Directors.

Section 7. The securities of the Association may be bought, sold, or exchanged only upon the written order of two of the following: chairman of the Investment Committee, vice chairman of the Investment Committee, treasurer, and administrative secretary.

Section 8. The business office of the administrative secretary shall keep proper accounts of all financial transactions of the Association.

Section 9. The accounts of the Association shall be audited and approved annually by a chartered or other competent public accountant selected by the Board of Directors.

Section 10. The administrative secretary shall have the authority to enter into contracts for the Association, but contract authorizations must be within the budget authorizations made by the Board of Directors.

Section 11. The activities of the Gordon Research Conferences shall be administered according to procedures established by the Board of Directors.

Constitution—*Article XII*

Section 1. Amendments to this constitution shall be approved by the Board of Directors after publication in substance in SCIENCE and THE SCIENTIFIC MONTHLY at least one month prior to an annual meeting of the Association and ratified by a two-thirds vote of the Council members present in a Council session of that meeting. Ratified amendments shall be effective upon adoption and shall be published promptly in SCIENCE and THE SCIENTIFIC MONTHLY.

Bylaws—*Article XII*

The bylaws may be amended by majority vote of the Board of Directors, provided notification of the proposed amendment has been mailed to each member of the Board at least twenty (20) days prior to the meeting.

HOWARD A. MEYERHOFF
Administrative Secretary, AAAS